ASTRONOMY®

August 1992 U.S. $2.95
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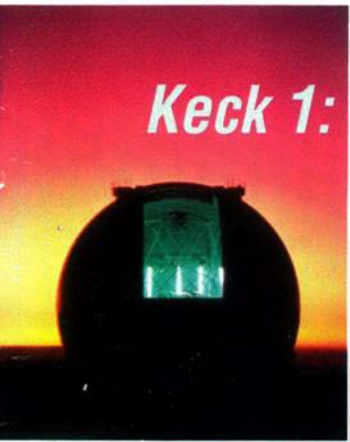
BIG BANG BREAKTHROUGH



Keck 1: World's Biggest Eye Opens

Hunting for Near-Earth Asteroids

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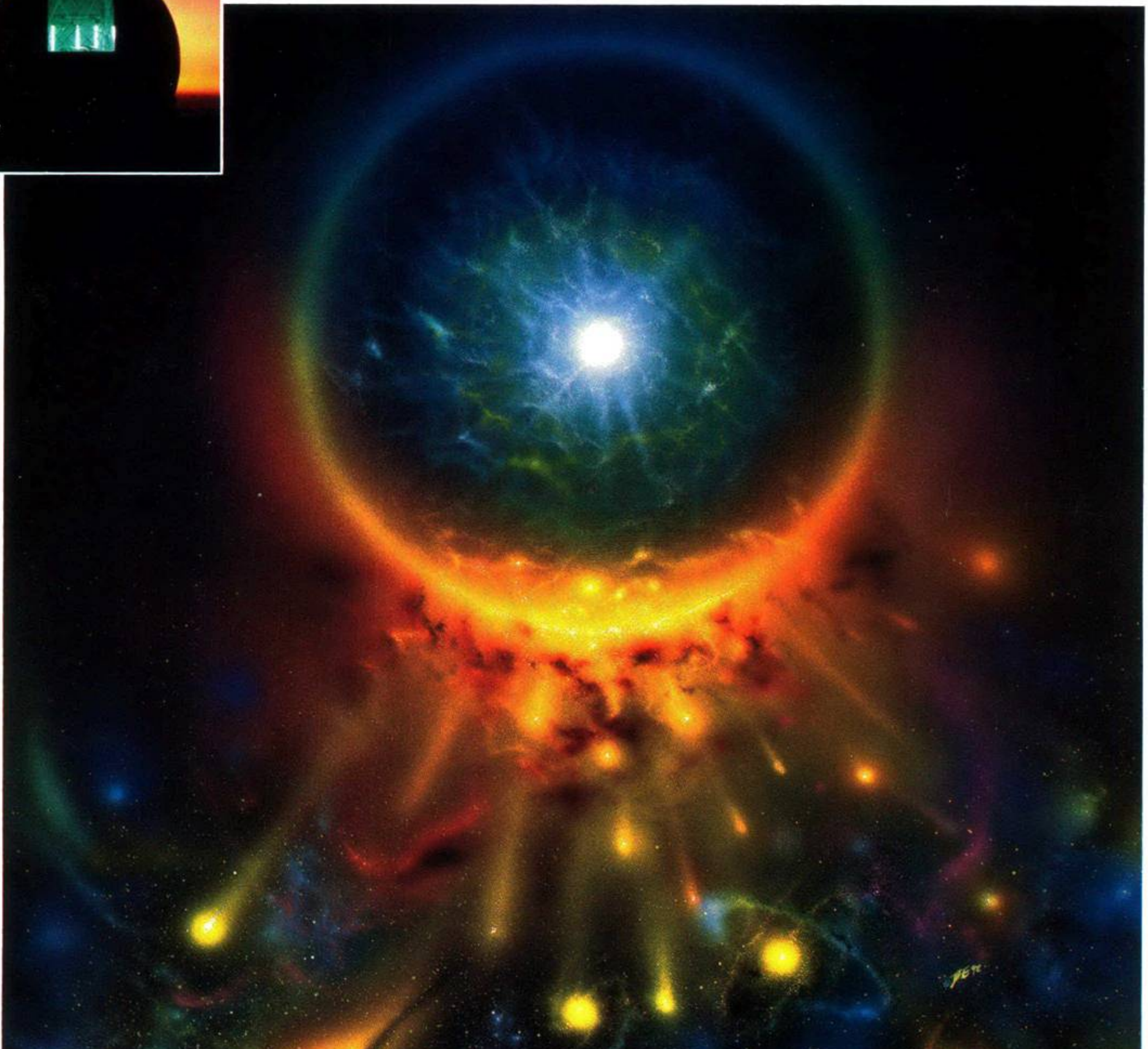

The Explosive Beginning of the Universe

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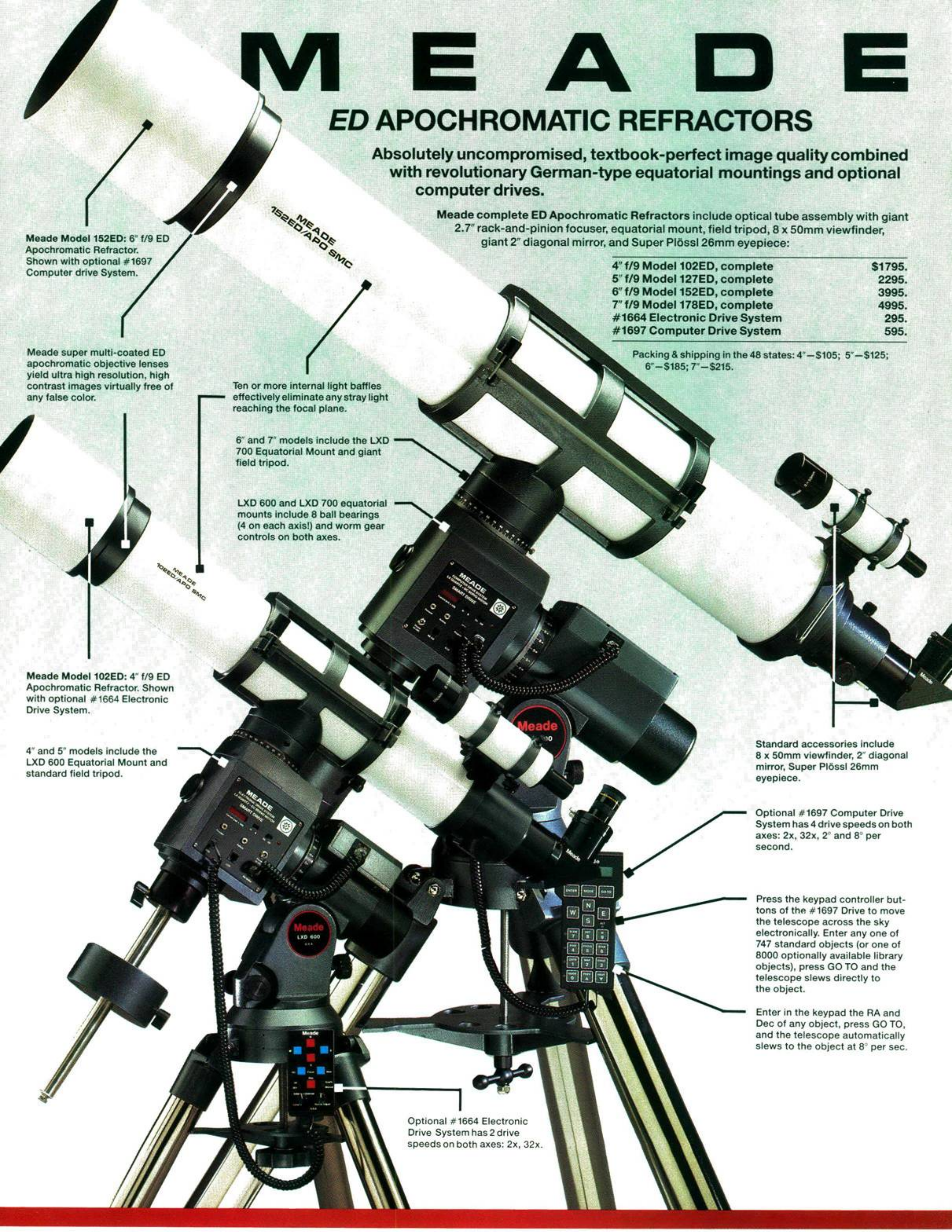
ED APOCHROMATIC REFRACTORS

Absolutely uncompromised, textbook-perfect image quality combined with revolutionary German-type equatorial mountings and optional computer drives.

Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7" rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2" diagonal mirror, and Super Plössl 26mm eyepiece:

4" f/9 Model 102ED, complete	**$1795.**
5" f/9 Model 127ED, complete	**2295.**
6" f/9 Model 152ED, complete	**3995.**
7" f/9 Model 178ED, complete	**4995.**
#1664 Electronic Drive System	**295.**
#1697 Computer Drive System	**595.**

Packing & shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.



Meade Model 152ED: 6" f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer drive System.

Meade super multi-coated ED apochromatic objective lenses yield ultra high resolution, high contrast images virtually free of any false color.

Meade Model 102ED: 4" f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4" and 5" models include the LXD 600 Equatorial Mount and standard field tripod.

Ten or more internal light baffles effectively eliminate any stray light reaching the focal plane.

6" and 7" models include the LXD 700 Equatorial Mount and giant field tripod.

LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis!) and worm gear controls on both axes.

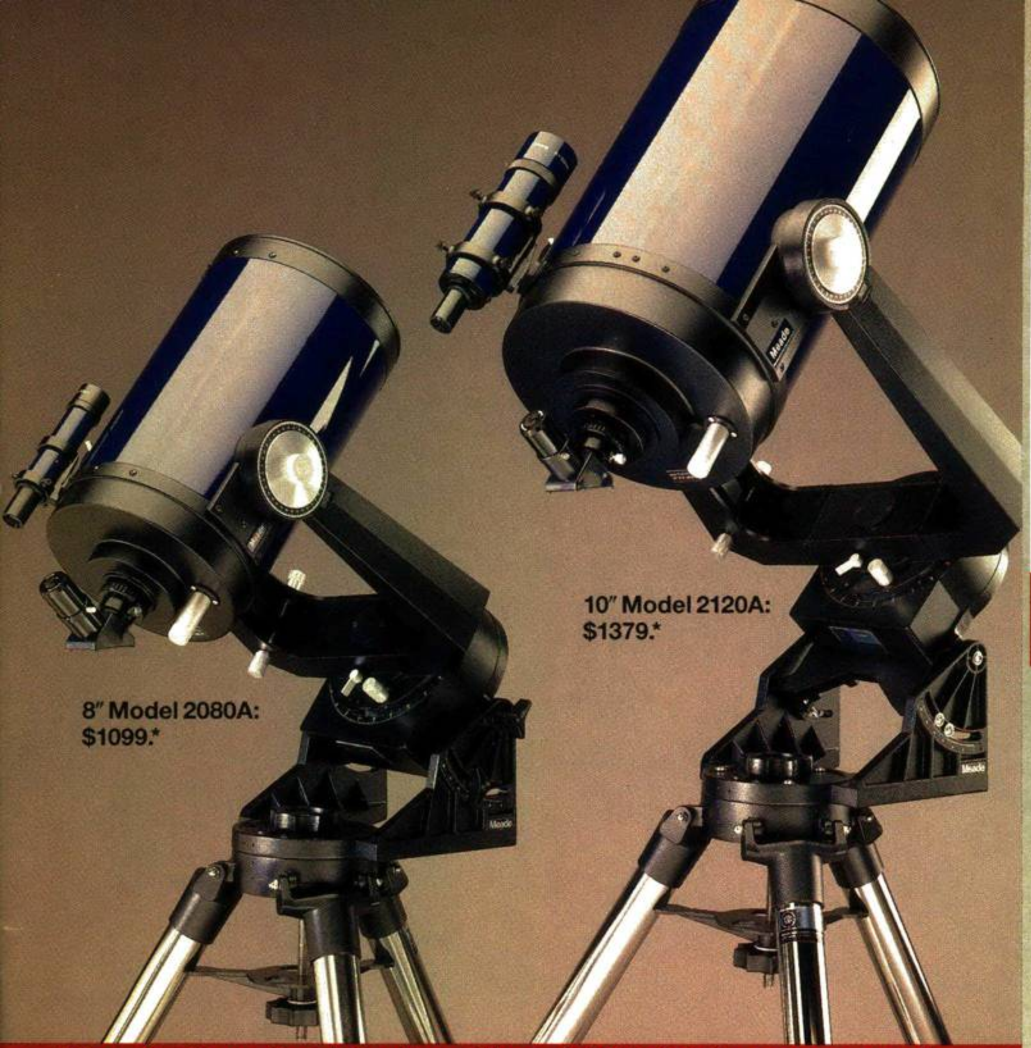
Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

Standard accessories include 8 x 50mm viewfinder, 2" diagonal mirror, Super Plössl 26mm eyepiece.

Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.



10″ Model 2120A:
$1379.*

8″ Model 2080A:
$1099.*

4″ Model 2045D:
$599.*

Meade Standard Series 8″ and 10″ SCT's: advanced technology at economical pricing levels.

No other comparably-priced Schmidt-Cassegrains offer the optical and mechanical features of the Meade Standard Series:

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■ **Mountings:** Highly stable, low vibration fork mountings designed for advanced applications such as long-exposure astrophotography, mountings that can carry more than *twice the payload* of competing small German-type mounts.

■ **Standard-Equipment Motor Drive System:** Not an add-on, but *a built-in 5.75″ worm gear drive that is the most accurate available on any SCT in this price range.*

■ **Variable-Height All-Metal Field Tripods:** The finest tripods yet developed for SC telescopes, the ultimate in rigidity and low-damping time.

■ **Optional Systems:** Unlike competing German-mounted SCT's with small worm gears, Meade Standard Series SCT's permit almost unlimited growth potential—use the **#46 Dual-Axis Drive Corrector** for deep-space photography with the **Off-Axis Guider** system; **#929 2″ Diagonal** with **2″ Super Wide Angle** eyepieces for breathtaking wide-field observing; and much more. ***See the Meade catalog for details!***

4″ Model 2045D: the Ultraportable Meade SCT

For the beginning astronomer the lightweight and easy-to-use Meade 2045D packs a powerful potential for serious observing. As a second telescope for the advanced amateur, the 2045D permits wide-ranging observations in locations inaccessible or inconvenient to larger instruments. Each telescope includes optics manufactured to the same high performance standards as larger Meade models. The DC drive system operates from a micro battery pack for convenient field use. Full accessorization is available for virtually any field application.

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Specifications: 8″ Model 2080A – Complete with 8″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls and locks on both axes; 5.75″ worm gear motor drive system (115v./60Hz); eyepiece-holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 6 x 30mm viewfinder; equatorial wedge; variable-height all-metal field tripod. .... **$1099.**

Model 2080B – Identical to Model 2080A, but in addition with Super Multi-Coated optics. .... **$1149.**

Packing & shipping on either 8″ model in the 48 states: . **$95.**

Specifications: 10″ Model 2120A – Complete with 10″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75″ worm gear motor drive system (115v/60Hz); eyepiece holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 8 x 50mm viewfinder; equatorial wedge; variable-height all-metal field tripod. .... **$1379.**

Model 2120B – Identical to Model 2120A, but in addition with Super Multi-Coated optics. .... **$1449.**

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☐ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, visit one of the hundreds of Meade dealer showroom locations throughout the USA; or contact one of the authorized mail-order dealers at left. Or call Meade Instruments toll-free at 1-800-854-7485 (in California 714-556-2291).**

☐ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

☐ The all-new **1992 Meade General Catalog** – $3.00 postpaid – is available from any authorized Meade dealer or directly from Meade Instruments.

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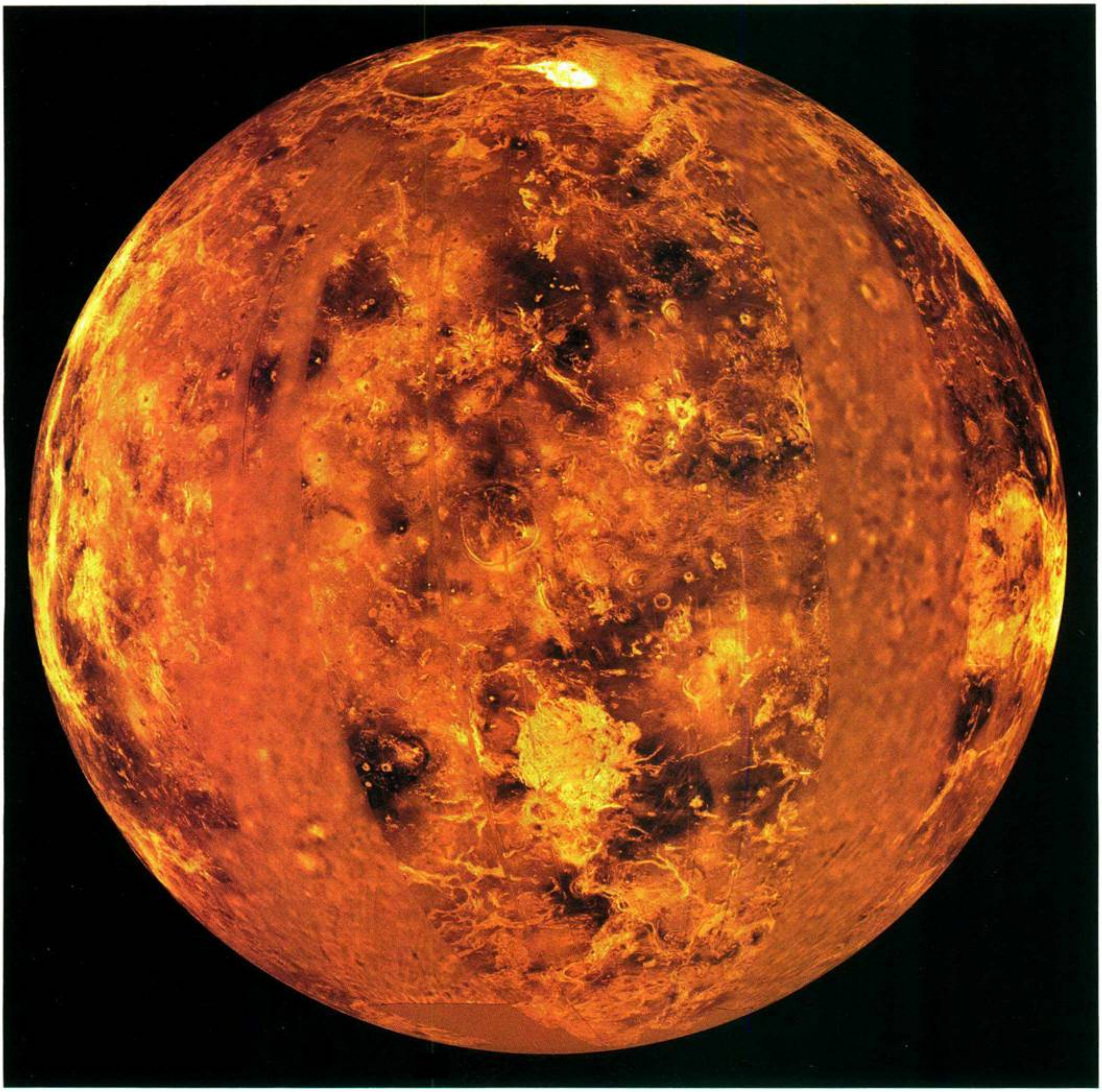
ON THE COVER: After the big bang, giant ripples formed in the expanding mix of matter and energy that was the early universe. Astronomers recently announced the first direct evidence for the primordial ripples. To learn more, turn to page 42. Illustration by Robert Eggleton. (Inset photo of W. M. Keck Observatory courtesy California Association for Research in Astronomy.)



THE LATEST VIEWS OF VENUS reveal a planet pockmarked with impact craters and volcanic calderas. This global view of the planet is a mosaic of radar images from the Magellan and Pioneer Venus orbiter crafts. The color is a simulated hue based on color images recorded by the Soviet Venera 13 and 14 probes. For other revealing views of the volcanic planet, see page 16.

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ASTRONOMY (ISSN 0091-6358) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial telephone: (414) 796-8776; Advertising and Dealer Orders: (800) 558-1544; Customer Service inquiries: (800) 446-5489 weekdays 8:30 a.m. - 5:00 p.m. Central Time; Consumer product and subscription inquiries: (800) 533-6644 7 days a week, 24 hours a day; Fax (414) 796-0126. Copyright ©1992 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Second-class postage paid at Waukesha, WI, and additional mailing offices. Allow six to eight weeks for new subscriptions and changes of address. New subscriptions start with the current issue. Subscription price: 1 year, $24. All foreign: add $6 per year; please remit in U.S. funds. GST #R122713209. Send editorial and business inquiries and submissions to the address above. Not responsible for unsolicited materials. ASTRONOMY is indexed in *The Reader's Guide to Periodical Literature*. Microfilms of ASTRONOMY available from University Microfilms, Inc., 300 North Zeeb Road, Ann Arbor, MI 48106. Printed in the U.S.A. POSTMASTER: Send address changes to ASTRONOMY, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Canadian second-class postal permit no. 545775.

The Audit Bureau

Behind the Scenes

ASTRONOMY'S STARTLING NEW UNIVERSE

When astronomers working the data from the Cosmic Background Explorer satellite found evidence for "ripples" — minute temperature fluctuations — in the faint microwave radiation from the early universe, the result made headlines around the world. In a single stroke the big bang model received tremendous support, and pundits spoke solemnly of discerning the structure of creation and seeing the face of God.

Well, pundits always talk like that. But all the same, this new finding (if confirmed) truly is one of the most significant astronomical discoveries in history. And apart from the support it gives to the big bang model, the discovery also offers cosmologists a much-needed way out of a tight squeeze.

Up until now, observations of the background radiation showed that the big bang explosion was incredibly smooth. This put cosmologists in a bind because somehow, almost magically, galaxies began to form soon after that seamless explosion. But how could the universe make something out of nothing? Like dandelions in May, ingenious hypotheses sprang up, but for lack of data no one could truly test them. Cosmologists might have been excused for thinking they were trapped in some kind of enormous Down East joke, forever unable to get from theah to heah.

But by painstakingly looking for and finally locating the big bang's missing link, George Smoot and his colleagues (see page 48) have given theorists a powerful way to chop through cosmology's theoretical weedpatch. If nothing else, the new crop of theories to come will occupy a corner of the field that is constrained far more tightly.

Another astronomy breakthrough comes with the completion of the 10-meter Keck telescope on Hawaii's Mauna Kea. This mammoth telescope, whose main mirror stretches 33 feet across, can see deeper into space than any other optical instrument we possess. The completion of the Keck scope also marks a renewal of astronomy, for it is just the first of a new generation of big ground-based telescopes to come. As the feature story on page 28 shows, the Keck scope will soon bring results to alter forever our views of stars, nebulae, and galaxies.

As a backyard observer I often feel a sense of renewal after the year glides past its midpoint. August nights usually hold much of summer's warmth, but the change of seasons is already under way. Days become noticeably shorter, and the Pleiades stand high in the east before the growing daylight drives them from sight.

Some observers feel rededicated each spring when they spot the glories of Scorpius and Sagittarius rising just before the Sun. Others of us find our renewal in seeing the lovely glittering Pleiades as a dew-drenched summer's dawn arrives. It makes a wonderful promise of blazing winter sky sights to come.

Sincerely,

Robert Burnham

Robert Burnham
Editor

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I.C.D., The Hearst Corp., New York, NY 10019
Canadian Newsstand Distribution
Telemedia Dist., Toronto, Ontario M4S3B3

Letters

Theft at Texas Star Party

The Texas Star Party, held each spring at the Prude Ranch in Fort Davis, Texas, holds one of the great spots in the hearts of most amateurs. The event is one of the largest get-togethers in the hobby, features inky black skies, and has a perfect record for coming off without a hitch.

Until this year, that is. Unfortunately I must inform the readers of ASTRONOMY of an unfortunate incident at the 1992 Texas Star Party. Two of our vendors at the 1992 star party, Bethany Sciences and a dealer for Meade Instruments Corp., were victimized by a theft of merchandise.

Items taken from Bethany included a knife made from a section of iron meteorite, a meteorite specimen from Mundrabilla, Western Australia, and a paperweight with a white meteorite from Norton County, Kansas. The Meade dealer lost two eyepieces.

It's regrettable that someone in our hobby must stoop to thievery to acquire objects they think they need. Perhaps they will read this and come to their senses. The items may be returned to me at P.O. Box 386, Wylie, Texas 75098, and they will be returned to the owner with no questions asked. All of us associated with the Texas Star Party most assuredly hope this never happens again at our event or any other gathering of amateur astronomers. — *Bobby R. Braley, Jr., Chairman, Texas Star Party, Southwest Region of the Astronomical League, Wylie, Texas*

Historical Sungrazers

I greatly enjoyed Gerrit Verschuur's article "Mysterious Sungrazers" (April 1992). Thomas W. Webb's *Celestial Objects for Common Telescopes* describes several cases of suspected sungrazers between June 6, 1761, and April 4, 1876. Commenting on one of them, Webb wrote: "Comets, from the endless diversity of their paths, must occasionally traverse the solar disk, and the opportunity of such a background would be most valuable for acquiring more information as to their nature."

Webb continued, "This actually took place on June 26, 1819, but it was not known until afterwards, when a controversy arose as to whether the stranger had been visible. Pastorff of Buchholtz, near Frankfort, maintained that he had that day seen on the Sun a round dark nebulous spot with a bright point in the center."

Verschuur commented that sungrazing comets may not be visible due to their small size "except during a total

[continued on page 12]

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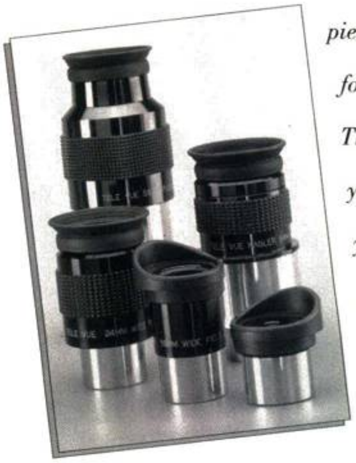
Patented Tele Vue eyepiece designs started a "space-walk" revolution. Bringing you far more field, sharpness and contrast than ever before. And still today, genuine Tele Vue Plössl, Wide Field, Panoptic and Nagler eyepieces deliver greater apparent field and edge sharpness than any other brand. All models have rubber eyeguards and each eyepiece is full field inspected before it leaves our hands for yours.

The more eyepieces you order, the more FREE items you receive. So, get your friends together and pool your orders for best selection. This offer ends September 30, 1992. Applies to merchandise in-stock at time of order. Take a Tele Vue out tonight and discover the eyepieces designed for a lifetime of viewing enjoyment.

> "After seeing the recent ad with all the letters touting (competitive) eyepieces, I had to respond. I consider myself a very critical observer. Using a 10" f/5.6, I found the Tele Vue 40mm Wide Field superior to the (competitor) in sharpness, both center and edge. I have used very expensive and inexpensive eyepieces. I have found none optically superior to Tele Vue for astronomical purposes." - Kenneth Drake, Houston Astronomical Society
>
> "Our observatory has a 16" f/5, and I recently tested my 26mm and 17mm Tele Vue against a new (5-element) competitive "Plössl". The Tele Vue eyepieces were much sharper, with more contrast. Sharpness at the edge of the field was far superior." - Steven Sherrod, TX
>
> "Your eyepiece (20mm Nagler) has given me the most pleasant case of insomnia imaginable." - Tom Lorenzin, Author of 1000 + Guide to Deep Sky Observing



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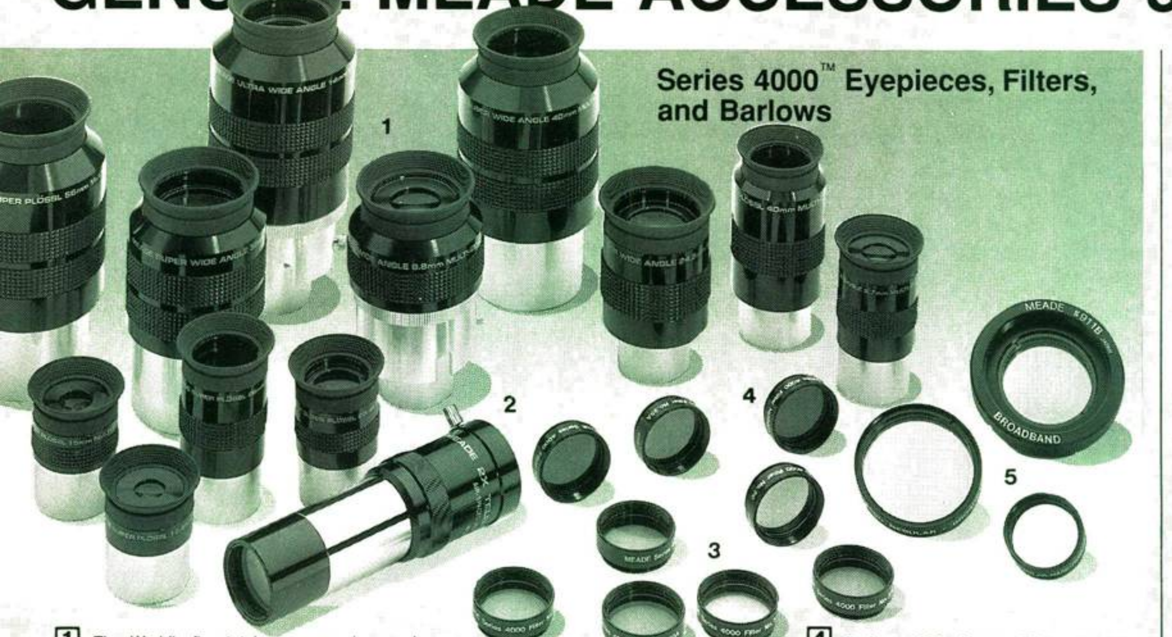

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1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$79.95** (2.49)
32mm(52°); **40mm**(44°); each **99.95** (2.49)
56mm (52°, 2") **219.95** (3.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm: 129.95 (2.49) **18mm: 139.95** (2.49)
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*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

3 **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets . Thread into virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.
each **$12.95** (1.79)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$42.95** (2.49)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green . **$42.95** (2.49)

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4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$14.50** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

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#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **87.95** (1.79)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (1.79)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.49)

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Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.49)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

Variable Tele-Extender:

Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.
$36.95 (2.49)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.
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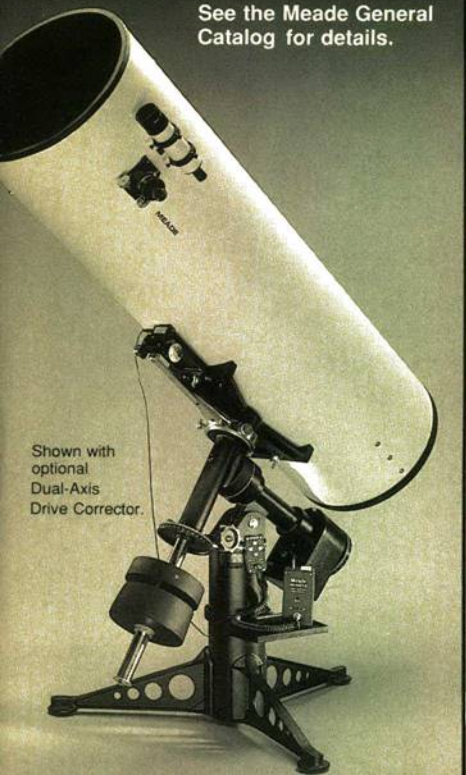

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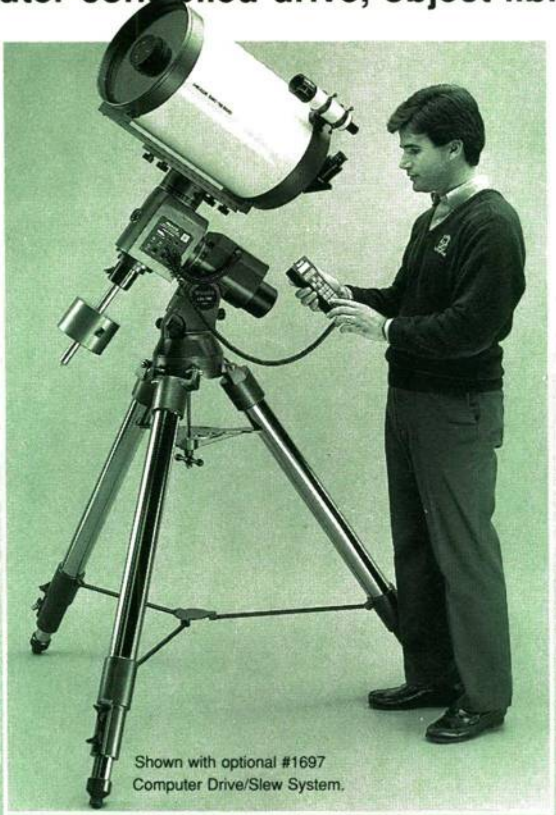

Shown with optional #1697 Computer Drive/Slew System.

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Packing and shipping in the 48 states: 8"—$105; 10"—125.; 12"—195.; 14"—245.

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■ **Delivery Schedule:** Meade 8" and 10" SSC models are available for prompt shipment; first deliveries on 12" and 14" models: early-1993.

■ For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.

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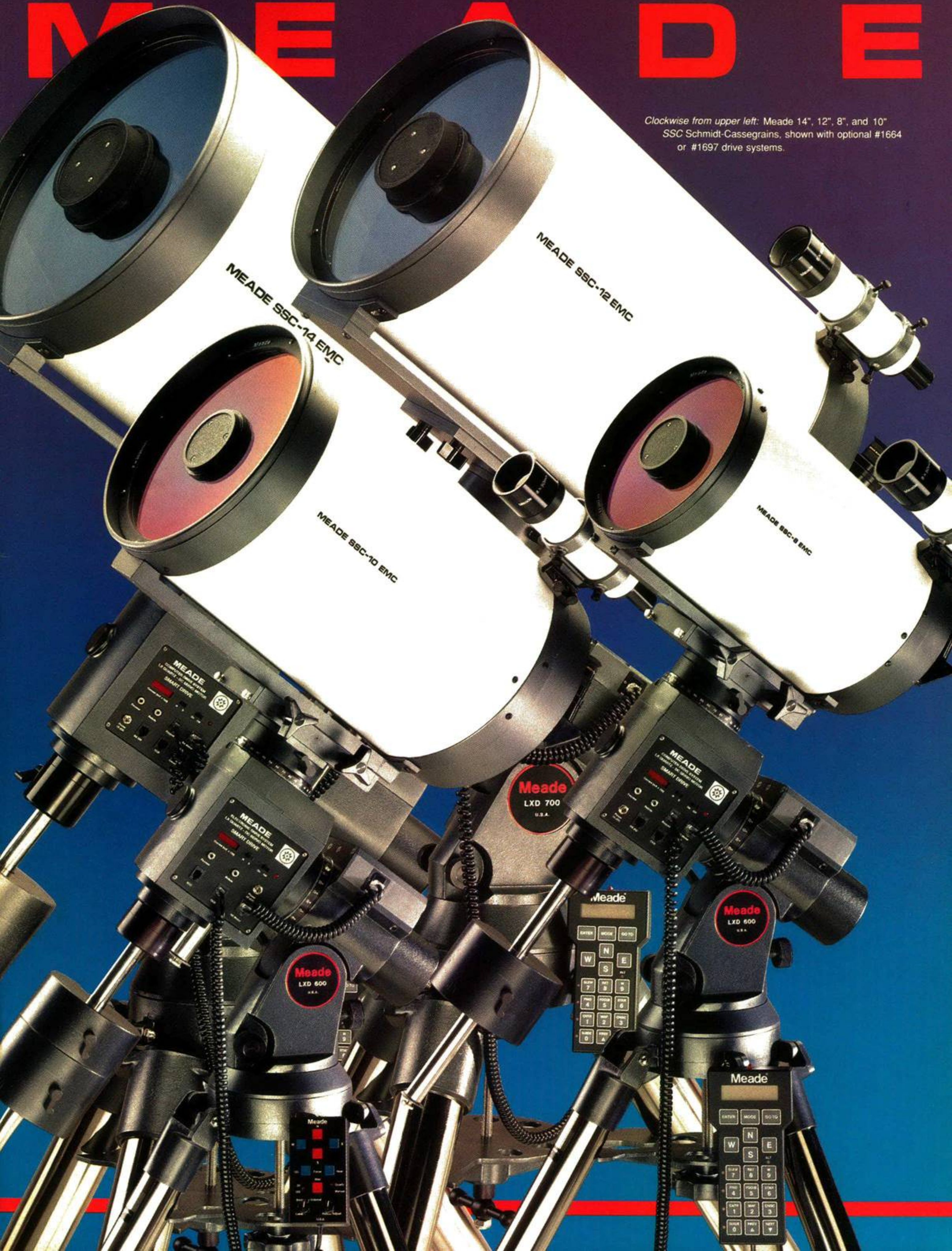
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Clockwise from upper left: Meade 14", 12", 8", and 10" *SSC* Schmidt-Cassegrains, shown with optional #1664 or #1697 drive systems.

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solar eclipse." But the possibility exists, however remote it might be, that someone could spot a sungrazer against the disk of the Sun itself. — *Don Trombino, Deltona, Florida*

Gerrit Verschuur's article was a delight to read. I found a small item to take issue with, however. The Great September Comet of 1882 (1882 II) was not discovered during a total solar eclipse, as Gerrit L. Verschuur implies in his fine article. No doubt Verschuur intended to refer to the comet visible near the Sun only during the solar eclipse of May 17, 1882, and named Tewfik after the Khedive of Egypt. In his study of sungrazing comets, Brian Marsden accepts Tewfik as a member of the Kreutz sungrazing family, which includes Comet 1882 II.

Comet 1882 II was first spotted in the morning sky on September 1 by observers in the Southern Hemisphere. As Verschuur writes, it was one of the brightest of the sungrazers, visible in broad daylight near the uneclipsed Sun around the time of perihelion passage on September 17. Ten days later, after 1st-magnitude stars had disappeared in the morning twilight, 10° of the tail was still visible. Truly, 1882 II was one of the most spectacular comets of recorded history.

A third object spotted that year in broad daylight just above the Sun, between 10 and 11 a.m. local time on December 21, might have been a sungrazer. According to observers near Dundee, Scotland, the object was starlike, "of a milky white appearance, and seemed, when seen through the glass, to be of a crescent shape." This anonymous account was published in the December 29, 1882, issue of *Knowledge*, brought to my attention by Richard Baum and Cecil M. Botley, and reprinted in full in the June 28, 1976, issue of *Comet News Service*, which I edited. While suggestive, this curious observation is nonquantitative and unconfirmed, and can hardly be considered definitive.

The year 1882 was an extraordinary one for sungrazing and daylight comets. In addition to Tewfik and Comet 1882 II, observers also witnessed the brilliant Comet Wells (1882 I). When this sungrazer passed within six million miles of the Sun's surface on June 11, 1882, it was visible from many observatories in daylight. Unlike Tewfik and Comet 1882 II, however, Comet Wells was not a member of the Kreutz sungrazing family. — *Joseph N. Marcus, Omaha, Nebraska*

Dark Matter and Galaxies

Thanks for publishing Richard Monda's story "Shedding Light on Dark Matter" (February 1992). I was particularly struck by reading about Vera Rubin's measurements of the orbital velocities of stars in the spiral arms of galaxies and how dark matter might affect these measurements. Consider the following process to explain the formation of spiral arms in galaxies: Suppose some of the stars in the outer part of a galaxy's nucleus exceed the orbital escape velocity of the nucleus. We would expect these stars to move away from the galaxy in a hyperbolic path, the way a rocket escapes Earth's gravity. As the stars move away from the galaxy, their angular velocity would increase. This might cause the shape of the arms that trail behind the nucleus. Could this idea have any validity, or is there a gap somewhere in the reasoning? — *Victor Cohen, New York, New York*

Richard Monda responds: *The best-accepted theory among astronomers for the formation of spiral arms in galaxies is the density wave theory. As density waves travel throughout the galaxy, they plow into interstellar matter and trigger star formation. The density waves in a galaxy are believed to be established by the mutual self-gravity of its stars. Density wave patterns have been observationally demonstrated by researchers such as Debra Elmegreen at Vassar College.*

Certainly angular momentum does depend on distance from an object. For example, most of the angular momentum of our solar system lies in the orbits of the planets about the Sun. But to speak of the angular velocity of an object on a hyperbolic path is meaningless, since it is not on a closed orbit.

Further, the Sun is gravitationally bound to our Galaxy and is therefore not moving on a path out of the Galaxy. The best explanation for the measured rotation curves of galaxies is still nonluminous, dark matter.

Correction

The star trails photo published on page 68 of the May issue was taken by Robert Reeves. ☐

ASTRONOMY Magazine welcomes comments and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

PURSUING FAINT FUZZIES WITH BIFF SMOOTER

by Robert Bunge

Many people think I'm pretty much insane. Even other amateur astronomers. I might take my telescope out observing on a clear night and never once look at a bright Messier object or planet. Why, that would ruin my night vision!

Instead, I look for galaxies. Not just any galaxy, but faint ones. It's a good galaxy if I can see it with averted vision only. It's a great one if I have to nudge the telescope slightly to see a faint smudge against the sky.

You see, looking for the faintest of fuzzies can be addictive, kind of like the high one feels after running a marathon in a personal best time. As I find that faint fuzzy, I know that I've become one with my telescope.

Years of training and experience have paid off: The choice of the observing site. The choice of the night. The hours spent training eye and brain to use averted vision. The practiced knowledge of equipment, knowing just what it can and can't do.

I've tried to explain my addiction for faint galaxies and why I think it's a sport of sorts. But more often than not, people don't understand how in the world I can call it sport to drive an hour or so to the darkest skies around and stand out in the freezing cold just to look at a tiny, faint fudge of light that I can just barely see. Once while out, I called my favorite observing buddy, a strange fellow by the name of Biff Smooter, over to look at some really faint galaxy. He looked in the eyepiece for a loooooong time before saying, "That's nice Bob. Can't you find anything brighter?"

But bright isn't challenging, and a challenge is what I wanted — at first. Armed with a 10-inch telescope, I'd start the night with a bright Messier galaxy like M51. After a good look-see, I'd go for something fainter, perhaps a 12th- or 13th-magnitude galaxy from the New General Catalogue (NGC). Once I found the fainter galaxy, I strived to see detail, any detail. Is it round? Long and narrow? If it's an edge-on spiral galaxy, can I see any hint of a dust lane? It's fun to try to guess the Hubble classification of the galaxy before looking it up in a catalog.

While this type of observing was (and still is) great entertainment, I often wondered what more I could do. What about observing a small section of the sky in great detail? Indeed, I've found this to be extremely rewarding. My favorite technique is to pick a bright object — again, like M51 — and look for every known object within five or so degrees around the great spiral galaxy. I discovered that this approach required a lot of homework. Soon I could be found in the astronomical libraries of nearby colleges, asking if I could examine a copy of their Palomar Observatory Sky Survey.

In time, this approach led to another approach — my current one, sparked by a friend who asked what my reason was for looking at faint galaxies.

"Why should I look at that galaxy?" he asked. "What's there to see?"

"Why, you'll see nearly 50 galaxies just *near* M51," I replied.

This line of questioning led me to a new line of thinking. Wouldn't it be great to discover something new about all these faint objects I find? After all, isn't that what makes *Burnham's Celestial Handbook* tower above most other observing handbooks? Why, you can look at M13 and learn about what makes it tick.

So one of my recent projects was to use my personal computer to sort a massive catalog of 13,000 galaxies by size so as to come up with a list of the dozen galaxies in the Northern Hemisphere that appear largest in the sky. I was fascinated by the surprising results. The list included not only such classics as M31 and M81 but objects more or less unknown to the amateur community — the Draco and Ursa Minor dwarf galaxies, for instance. Could these even be seen with amateur telescopes?

Standing on my pad of concrete one chilly spring evening, I called Biff over to my 10-inch reflector. Overhead, the Big Dipper hung bright in the sky. Below, in the eyepiece of the telescope, was the Ursa Minor dwarf galaxy. With my lowest-power eyepiece, the galaxy was visible only as a slight brightening against the background sky. Biff stared in the eyepiece for some time before admitting defeat. I urged him to try again, and to move the telescope back and forth a field or two around where I had it centered.

"Bob, that's got to be the faintest one you've found yet," Biff declared.

"It's faint all right, but it's even closer to Ohio then M31 is," I replied.

"Let me know when you find something interesting," Biff said. ☐

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Completely revised and updated since it was privately printed in 1966, the handbook provides names, celestial coordinates, classification, and full physical descriptions for over 7,000 deep-sky objects that are accessible to observers with telescopes in the 2" to 12" range. This information—when used with a star atlas—enables you to find and locate almost every object of interest.

Burnham groups the objects according to the constellation in which they appear, and catalogs the stars by type. Each constellation is described in four sections:

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- Variable stars
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- Descriptive notes

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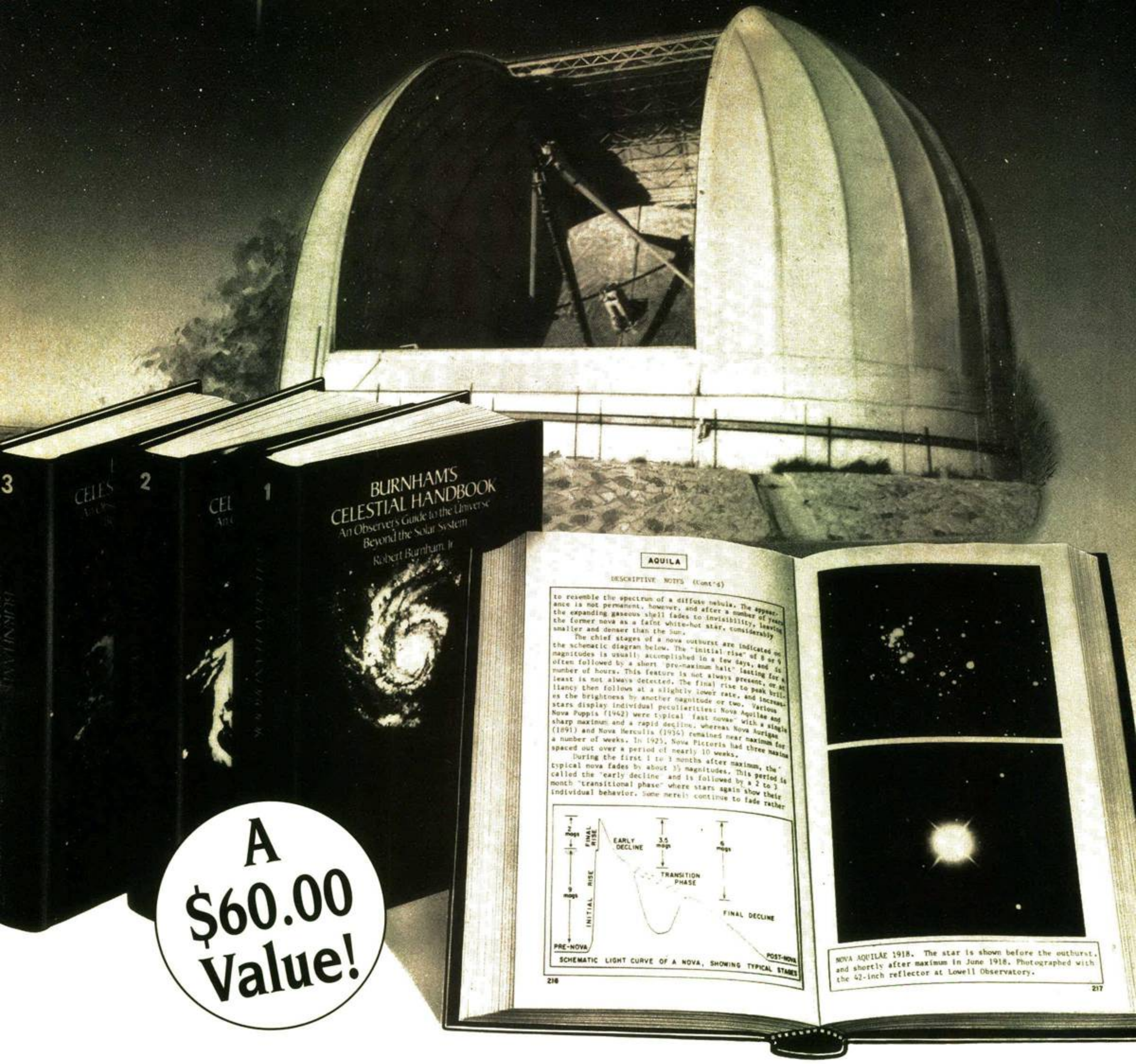
The handbook contains innumerable finder charts, graphs, and tables plus 660 aesthetically appealing photographs, many of them taken by the author with the 300mm Lowell Observatory telescope used to take the discovery plates of Pluto.



AQUILA

DESCRIPTIVE NOTES (Cont'd)

to resemble the spectrum of a diffuse nebula. The appear-
ance is not permanent, however, and after a number of years
the expanding gaseous shell fades to invisibility, leaving
the former nova as a faint white-hot star, considerably
smaller and denser than the Sun.
The chief stages of a nova outburst are indicated on
the schematic diagram below. The "initial rise" of 8 or 9
magnitudes is usually accomplished in a few days, and is
often followed by a short "pre-maximum halt" lasting for a
number of hours. This feature is not always present, or at
least is not always detected. The final rise to peak bril-
liancy then follows at a slightly lower rate, and increas-
es the brightness by another magnitude or two. Various
stars display individual peculiarities: Nova Aquilae and
Nova Puppis (1942) were typical "fast novae" with a single
sharp maximum and a rapid decline, whereas Nova Aurigae
(1891) and Nova Herculis (1934) remained near maximum for
a number of weeks. In 1925, Nova Pictoris had three maxima
spaced out over a period of nearly 10 weeks.
During the first 1 to 3 months after maximum, the
typical nova fades by about 3½ magnitudes. This period is
called the "early decline" and is followed by a 2 to 3
month "transitional phase" where stars again show their
individual behavior. Some merely continue to fade rather

SCHEMATIC LIGHT CURVE OF A NOVA, SHOWING TYPICAL STAGES

216

NOVA AQUILAE 1918. The star is shown before the outburst, and shortly after maximum in June 1918. Photographed with the 42-inch reflector at Lowell Observatory.

217

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MAGELLAN MISSION ENTERS NEW PHASE

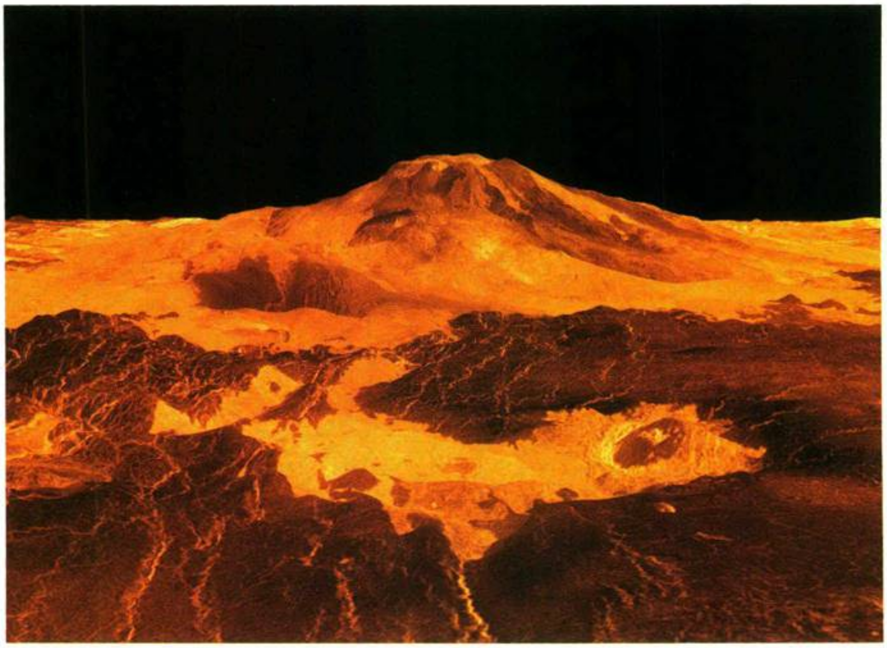
The highly successful Magellan spacecraft is nearing the end of its planned radar imaging of Venus. Since September 1990, Magellan has been mapping Venus' cloud-covered surface by sending radar beams through the clouds. This technique allows astronomers to reconstruct images of the otherwise hidden surface features. So far, about 97 percent of the surface has been mapped, with about 30 percent mapped with stereo 3-D imaging.

The image-taking has been going on for three Venus days (each Venus day equals 243 Earth days), with Magellan taking one Venus day to complete one cycle of mapping around the planet. On September 14, the third and last cycle of radar imaging will end and the next phase of the mission, mapping the gravity of the Venusian surface, begin.

This cycle, Magellan's fourth circuit around Venus, will last another 243 days. During that time, Magellan will take few images. Instead, astronomers will use the signal from Magellan's transmitter as a radar altimeter. Changes in the spacecraft's altitude during each orbit will tell astronomers about variations in the gravitational field around Venus over a zone extending from 40° north latitude to 30° south. This should allow astronomers to study the crust of Venus to determine what the surface layers are made of. Unlike Earth, Venus shows no signs of plate tectonic activity — no plates of crustal material moving around the planet. On Earth, when plates collide, they buckle and form mountains. But what creates the mountains and highlands of Venus? The gravity-field map should help determine the answer.

The fourth cycle of data-taking around Venus could be the last. When the gravity mapping ends in mid-May, 1993, current NASA plans (mostly dictated by tight budgets) call for Magellan to be turned off.

Currently Magellan is limping along with one of its transmitters out of commission and the second hampered by a very weak signal. Nevertheless, project scientists feel an extended mission is possible. They would like to send Magellan through a series of passes through the extreme upper atmosphere of Venus. This "aerobraking" would convert Magellan's elliptical orbit into a circular one at about 110 miles up. At this close distance, Magellan could conduct further cycles of imaging and gravity mapping of selected areas but with much higher resolution. However, NASA has not allocated any funds for the aerobraking maneuvers, nor for the observations that follow.


NASA/JPL Multimission Image Processing Laboratory

A COMPUTER CREATED this simulated view of the Venusian surface based on images from the Magellan spacecraft. The viewpoint is 327 miles north of Sapas Mons, a volcano named for a Phoenician goddess, at an elevation of 2.5 miles above the fractured plains.

While the debate over Magellan's fate goes on, the ailing craft continues to send back spectacular images, including the view above. If Magellan is turned off in 1993, then images received between now and mid-September are likely to be the last we'll see from Magellan.

NEW RESULTS FROM HUBBLE

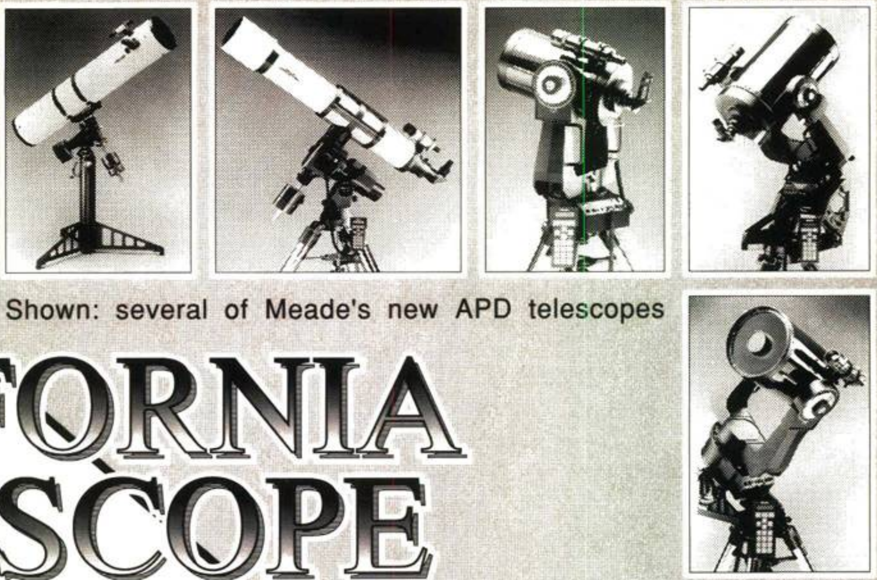
From our neighbors in the solar system to remote galaxy clusters, the Hubble Space Telescope continues to provide unprecedented views of the universe. On February 8, 1992, in conjunction with the Ulysses' flyby of Jupiter, Hubble's Faint Object Camera imaged a Jovian aurora. This is the first direct image of such an aurora taken in ultraviolet light and the best image ever of a Jovian aurora.

The photo (page 18) offers strong circumstantial evidence that Io plays a major role in Jovian aurorae. The aurora lies in the northern polar region of Jupiter, near where the magnetic field lines passing through the orbit of the Jovian satellite enter Jupiter's atmosphere. Other observations have shown that the volcanically active satellite spews large quantities of particles into the planet's magnetosphere. Thus the HST observations link the source of the particles and a mechanism for delivering them to Jupiter to the observed auroral region.

Far removed from the cool cloudtops of Jupiter is the torrid surface of one of the hottest stars yet discovered. Hubble's Planetary Camera clearly separated this star from the planetary nebula NGC 2440 in Puppis, which surrounds it. That allowed astronomers to make the most accurate estimate yet of the superhot star's temperature: at least 200,000 kelvins!

"The Hubble photo also reveals intricate structure in the nebula that was not discernible in photos made from the ground," according to astrophysicist Sara Heap, who led the team's effort. This is the first time the nebula's internal details — *which consist of numerous* filaments and streamers — have been seen in such detail.

Hubble astronomers have also located



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an unusual optical jet in a distant galaxy that may represent a new phenomenon. HST's Faint Object Camera zoomed in on NGC 3862, the sixth-brightest galaxy in Abell 1367, a rich cluster of galaxies in Leo. Astronomers knew that NGC 3862, a bright radio and X-ray source, harbored a radio jet, but this is the first optical photo to reveal the jet.

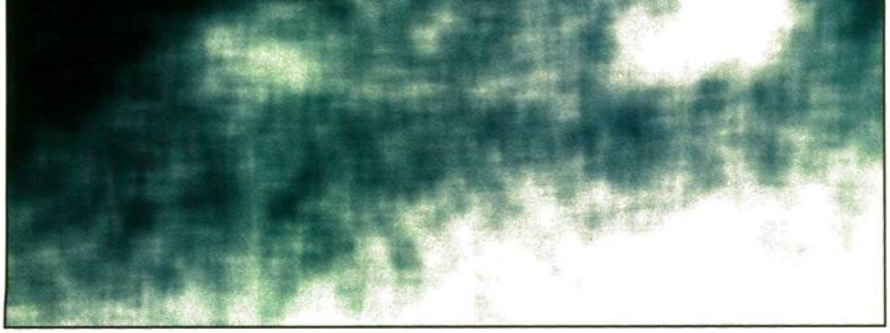
The jet doesn't fit easily into the standard model of jets. It is much shorter than most observed jets (about 750 light-years long) and much brighter at ultraviolet wavelengths than in visible light. Astronomer Philippe Crane of the European Southern Observatory, who led the observing team, believes "We are seeing a new class of phenomenon in galactic nuclei." He adds, "The jetlike feature was totally unexpected in this galaxy. This is typical of the kinds of discoveries that were expected from Hubble. We need to make further observations at many wavelengths to clarify the nature of this jet's emission."

NASA

A SUPERHOT STAR SHINES at the center of the planetary nebula NGC 2440. At a temperature of at least 200,000 kelvins, this star (seen as the bright white dot at the photo's center) is one of the hottest stars known.

Philippe Crane and NASA/ESA

KNOTS AND TWISTS characterize the newly discovered optical jet in NGC 3862. HST observations suggest that this jet may represent a new and unexpected phenomenon in galactic nuclei.


NASA

AN AURORA GLOWS in Jupiter's north polar region in this HST image. The shape corresponds to the position where magnetic field lines passing through Io's orbit enter Jupiter's atmosphere.

ICES DISCOVERED ON TRITON

The Voyager flyby in 1989 showed that methane ice exists on Triton, Neptune's largest satellite. Recent infrared measurements uncovered two more ices — carbon-monoxide and carbon-dioxide ices. This discovery is significant because astronomers previously had found this combination of ices only in comets. It strengthens the idea that Triton is a captured object and also the idea that comets, icy satellites such as Jupiter's Ganymede and Callisto, and the material that formed the cores of the outer planets have a common heritage.

The ices betrayed their presence in the spectrum of sunlight reflected from the surface of Triton. Dale Cruikshank (NASA Ames Research Center), Tobias Owen (University of Hawaii), and Tom Geballe (Joint Astronomy Center) used a new infrared spectrometer on the UK Infrared Telescope on Mauna Kea to measure the spectrum in the 1- to 5-micrometer region. The researchers now plan to look for these ices on Pluto and several other icy satellites.

WATER FOUND IN MARTIAN ROCKS

Meteorites believed to come from Mars contain up to 0.4 percent water. Although the rocks absorbed water after

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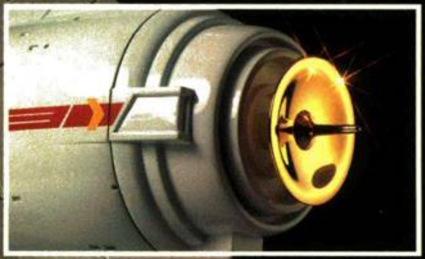

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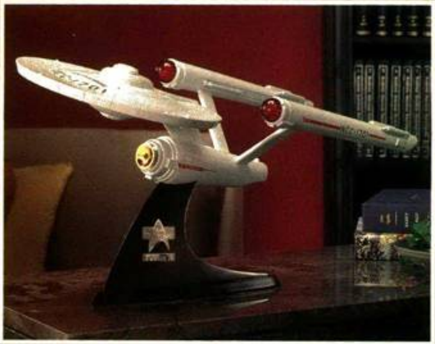

Actual size of the Starship Enterprise is 15" long.

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they landed on Earth, not all of the water in the rocks is of terrestrial origin. Scientists know this because some of the water contains different amounts of heavy oxygen isotopes than water on Earth contains, indicating that the rocks absorbed water while still on Mars.

Shergotty-Nahkla-Chassigny (SNC) meteorites all have similar compositions, which implies that they come from a single source. Most experts believe that the meteorites were expelled from Mars 180 million years ago when the Red Planet was hit by an asteroid.

The SNC meteorites do not confirm possible flooding on Mars, because their water could have come from rainwater or water vapor in the atmosphere. But they do yield clues about the early history of Mars as it accreted material to become a planet. Haraldur Karlsson of Texas Tech University and his colleagues reported the extraterrestrial nature of water in the SNC meteorites in the March 13, 1992 *Science*.

GO FOR LIGO

A new astronomical observatory got an important go-ahead in February. Scientists selected sites for the two facilities of Caltech's Laser Interferometer Gravitational Wave Observatory (LIGO). Astronomers designed the $210 million project to detect gravitational waves, ripples in the fabric of space-time predicted by Einstein's general theory of relativity. Each LIGO facility will look for passing gravity waves by detecting minute fluctuations in the length of a series of laser beams laid out in an L-shaped pattern. The project calls for two identical facilities — effects seen at both facilities at the same time are more likely to be from cosmic gravity waves; effects seen at only one facility could be noise from local seismic vibrations.

One LIGO detector will be built near Livingston, Louisiana, the other near Washington state's Hanford nuclear research facility. Construction is expected to begin by the end of the year.

TUNE INTO THE NASA CHANNEL

The little-known NASA Select television service offers a gold mine of information for space program fans. It delivers live mission coverage, documentary programs on space topics, and educational programming.

NASA Select programming starts at noon Eastern time Monday through Friday, and is shown in four-hour blocks that repeat at 4 p.m., 8 p.m., and midnight. The 2 p.m. (repeated at 6 p.m., 10 p.m., and 2 a.m.) program is specifically intended for classroom use. Programs such as press conferences and mission coverage preempt regular programming.

Many cable television companies now offer NASA Select. If your cable system doesn't, you may want to encourage them to do so. For home satellite dish owners, NASA Select can be found on SatCom F2R (72° west longitude), C Band, Transponder 13 (vertical polarization) with audio on 6.8 MHz.

Amateur News

ROCKLAND CLUB STAGES NEW SHOW

The familiar phrase "I'd walk a mile for a Camel" takes on new meaning when it comes to amateur astronomers and the distances they'll travel to participate in their hobby activities. How about "I'll drive 650 miles from North Carolina to New York on Friday, talk about astronomy on Saturday, and return home on Sunday."

That's just what author and amateur astronomer Tom Lorenzin did to participate in the Northeast Astronomy Forum on Saturday, March 14. Tom, along with comet expert John Bortle, the Hayden Planetarium's William Gutsch, and authors Phil Harrington and Richard Berry, made up the guest speaker roster at the day-long gathering, which attracted amateur astronomers from all over the northeastern United States and eastern Canada.

Hosted by the Rockland Astronomy Club of Pearl River, New York, the event was the first offering of a major telescope show and astronomy conference in the greater New York/New Jersey area. The club committed itself to almost $3,000 in expenses for speakers and professional assistance but everyone involved with the project was optimistic the event would break even. All it required was 300 paying visitors at $5 a head and the sale of raffle tickets. Would the club succeed? No one in the area had tried this type of event before.

When the doors opened at 9:00 a.m., people from twenty-five astronomy clubs made a mad dash to the registration table and then to the bargain-laden sales booths.

Twelve manufacturers and dealers of astronomy-related equipment, books, and computer software were set up and ready to sell their wares in the display hall. Exhibitors included Astronomy To Go, Bethany Sciences, CEB Metasystems, Columbia University Press, F. C. Meichsner Co., Handmade Telescopes, Learning Technologies, Lewis-Michaels Engineering, Pauli's Wholesale Optics, Roger Tuthill, Inc., TeleVue Optics, and Wholesale Optics of Pennsylvania.

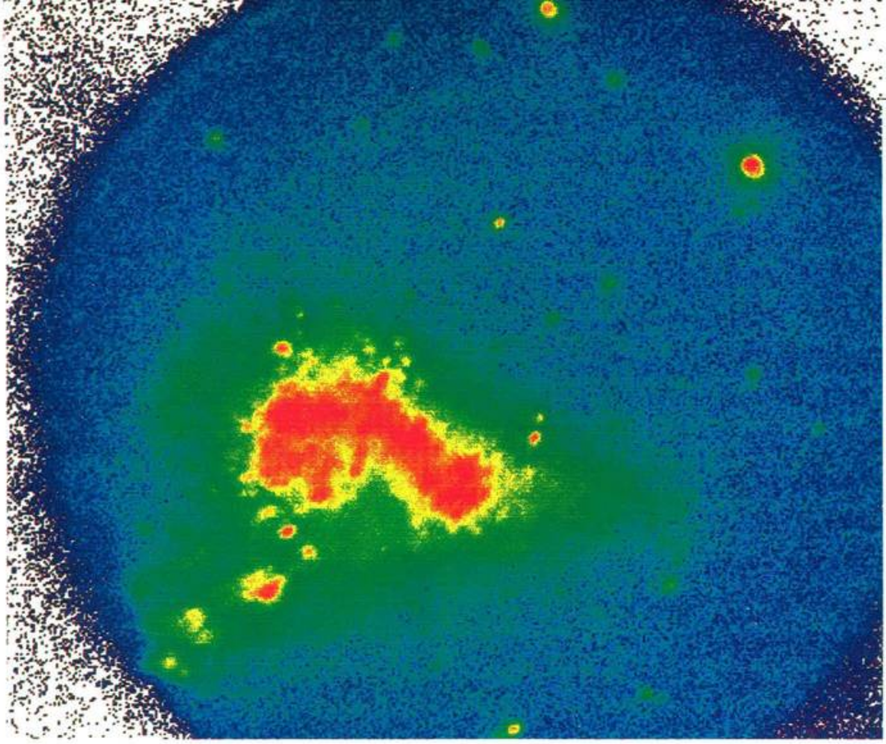
While dollars were changing hands in the exhibit area, the speaker program was underway in the adjacent auditorium. Two of the main features on the forum's schedule were Astronomy 101 talks for newcomers and novice amateurs and presentations in an inflatable Starlab planetarium where both adults and children could experience the wonders of the heavens. In addition, clubs were invited to talk about projects in which they are currently involved.

Between the talks, the sales booths, and the long list of door prizes (including an 8-inch Dobsonian telescope, a Nagler eyepiece, a meteorite, and copies of StarGaze and The Genesis Project computer software), it was a great day of activities.

Did the club break even? By day's end, more than 350 enthusiastic attendees had passed through the gates, assuring the Rockland Astronomy Club that their gamble had paid off.

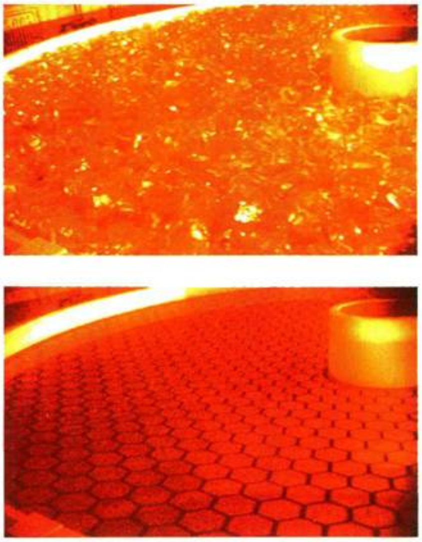
Based on comments and follow-up responses from those in attendance, the club is looking forward to seeing twice as many people attend next year's show, which will be held in early April.

If you would like to participate in the 1993 Northeast Astronomy Forum, please contact Donald Urban, 73 Haring Street, Closter, NJ 07624, or Allan Green, 110 Pascack Road, Pearl River, NY 10965. The club would especially like to hear from people who would be interested in being speakers. — *Donald Urban*



Center for Extreme Ultraviolet Astrophysics, University of California — Berkeley

THE SMALL MAGELLANIC CLOUD GLOWS in ultraviolet light in this image taken by an orbiting telescope last March. The Far Ultraviolet Space Telescope, or FAUST, flew on the shuttle Atlantis (see July 1992 Space News) and returned wide-angle images of selected targets around the sky. In this false-color image, hot young stars glow in vivid shades of red and trace star-forming regions in this nearby galaxy.



UA Steward Observatory

SPIN CASTING THE 6.5-METER MIRROR for southern Arizona's Multiple Mirror Telescope went flawlessly at Steward Observatory's mirror lab in April. These photos show part of the 10 tons of glass just prior to melting (top) and after the glass filled the spaces between more than 1,000 hexagonal cores that lined the mirror mold (above).

Space News

AXING AXAF IN TWO

The third of NASA's planned series of Great Observatories may have to become a little less great if it's to fly at all. Earlier this year, Congress cut the 1992 budget for the Advanced X-ray Astrophysics Facility (AXAF) by $60 million. With similar budget cuts looming as a certainty every year throughout AXAF's development, NASA has been forced to rethink the project or face the prospect that AXAF might never be completed in any form.

The satellite is intended to provide the most detailed look at the X-ray universe ever obtained, complementing the views from the first two Great Observatories, the Hubble Space Telescope and the Compton Gamma Ray Observatory, already in orbit.

So far, astronomers have completed a pair of AXAF's special cylindrical mirrors, and construction of AXAF has been proceeding on schedule for a launch in 1998. But the project now faces an uncertain future as NASA considers three options. One redesign, called AXAF-M (for Modifed), consists of the original plan of placing a multi-function spacecraft into low Earth orbit where it can be serviced by the shuttle, but scales back the spacecraft complexity, with fewer instruments and X-ray-gathering mirrors.

Options two and three both involve splitting AXAF into two craft, one for taking X-ray images and one for taking X-ray spectra. The spectroscopy mission would be launched into high Earth orbit on an expendable rocket at considerable cost savings over a shuttle launch. Under one option, the imaging mission would use the existing AXAF mirrors and would be placed into low Earth orbit by a powerful Titan-Centaur expendable rocket. In the third option, the imaging half of the mission would use a different and smaller set of mirrors, making for a lighter spacecraft that could be launched on a smaller and cheaper rocket such as an Atlas.

Although AXAF may yet survive in some form, the fourth and final Great Observatory, the Space Infrared Telescope Facility, has yet to receive any funding to get it off the drawing board.

NEW MIRROR FOR MULTIPLE MIRROR TELESCOPE

The Steward Observatory mirror lab in Tucson, Arizona, has cast a 6.5-meter-diameter mirror to replace the six 1.8-m mirrors of the Multiple Mirror Telescope. Ten tons of glass in 5 pound chunks were loaded by hand into the mirror mold in March. On March 29, the mirror lab team switched on the 21-foot-tall furnace. The glass became hot enough to flow among the 1,000 honeycomb cores of the mirror mold on April 2. During this melting phase, the furnace rotated 7 times per minute, causing the molten glass to flow into a curvature close to that of the desired final mirror surface.

On April 3, the glass finished melting, at which point the annealing process began. Annealing allows the mirror to cool evenly so no internal strain is left in the glass. The critical stage of slow annealing ended in mid-May. The furnace's rotation keeps the mirror's temperature uniform in the furnace while it slowly cools to room temperature.

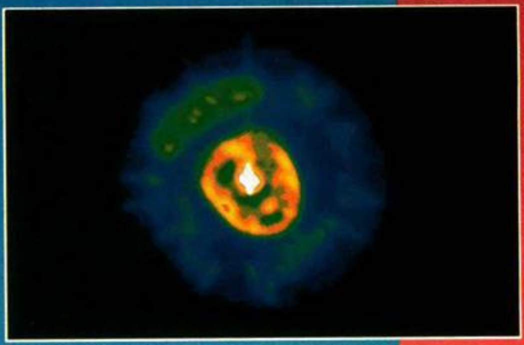
The mirror lab team expected to remove the mirror at the end of June. After cleaning, they will polish the mirror for 1 1/2 years. Preparations for a second 6.5-m mirror will begin in August and an 8-m casting will follow in 1994. ☐

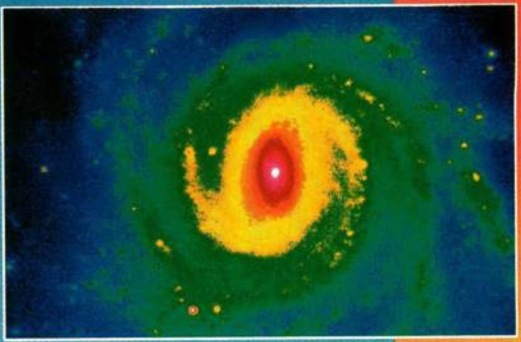
SEEING A

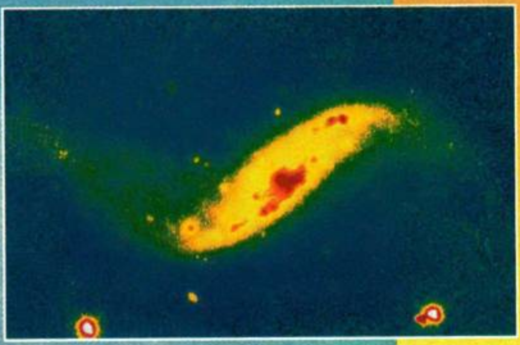
BRAVE NEW WORLD

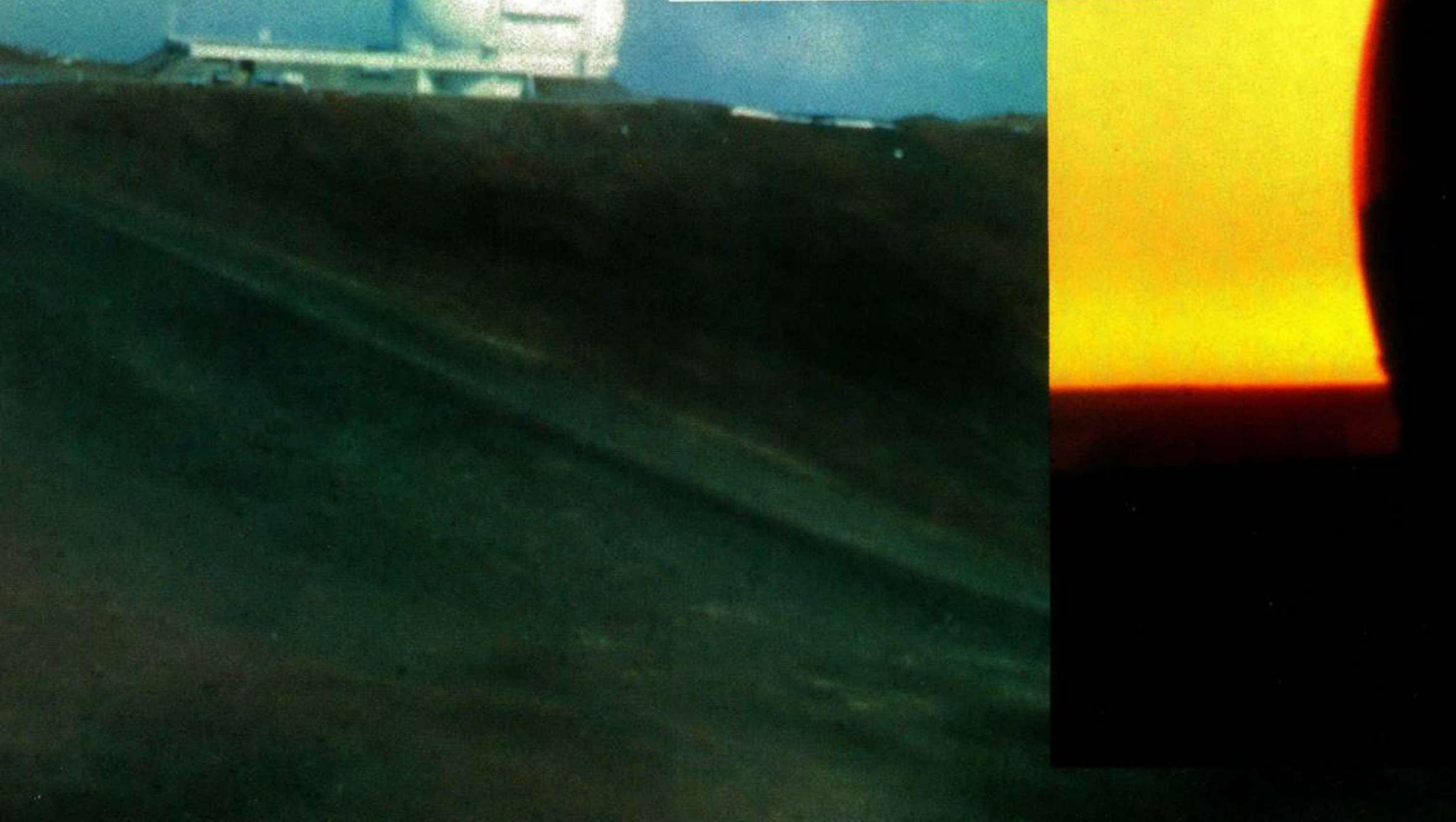
The world's largest optical telescope opens its big eye toward the heavens.

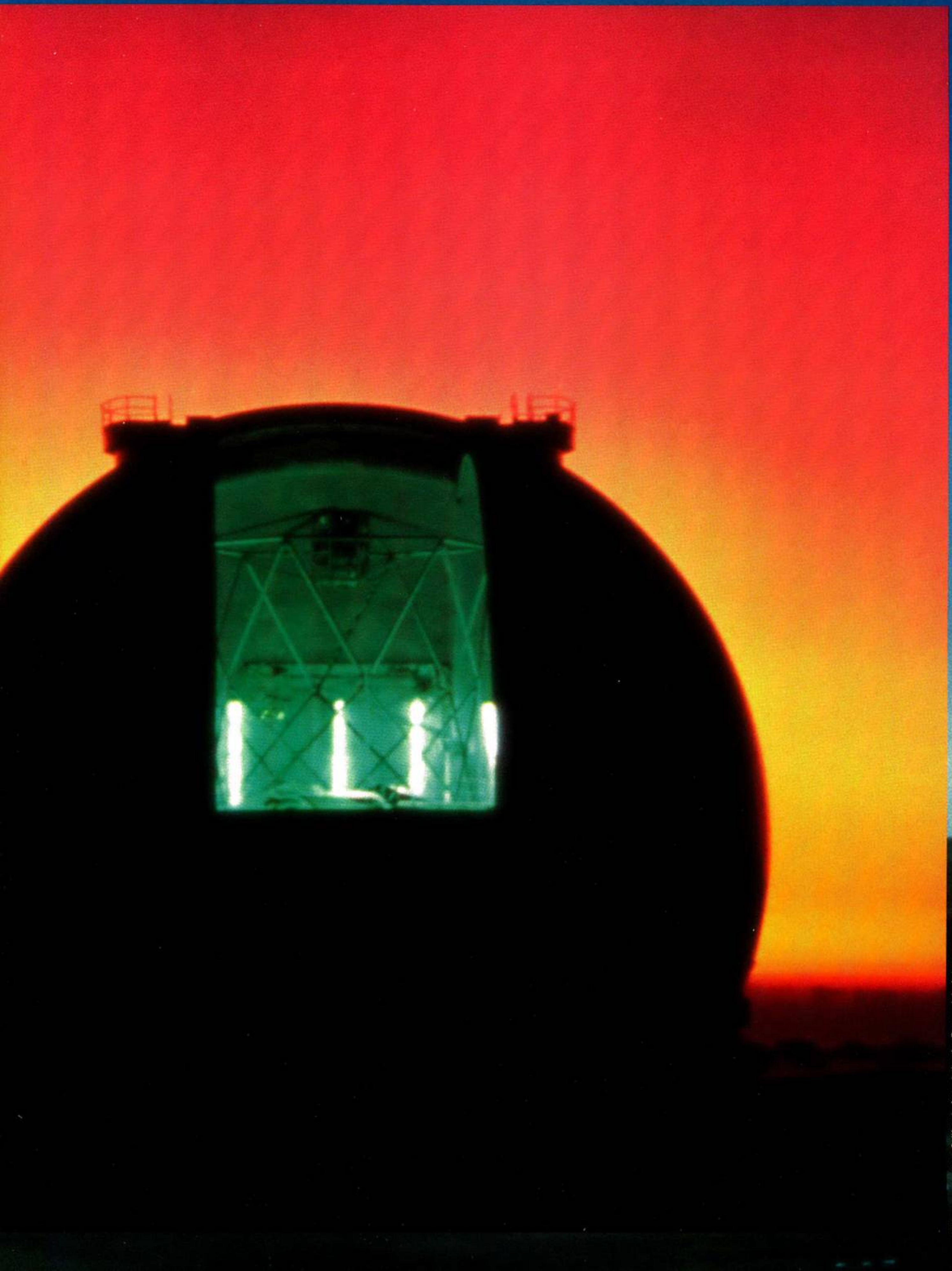
by Joel K. Harris



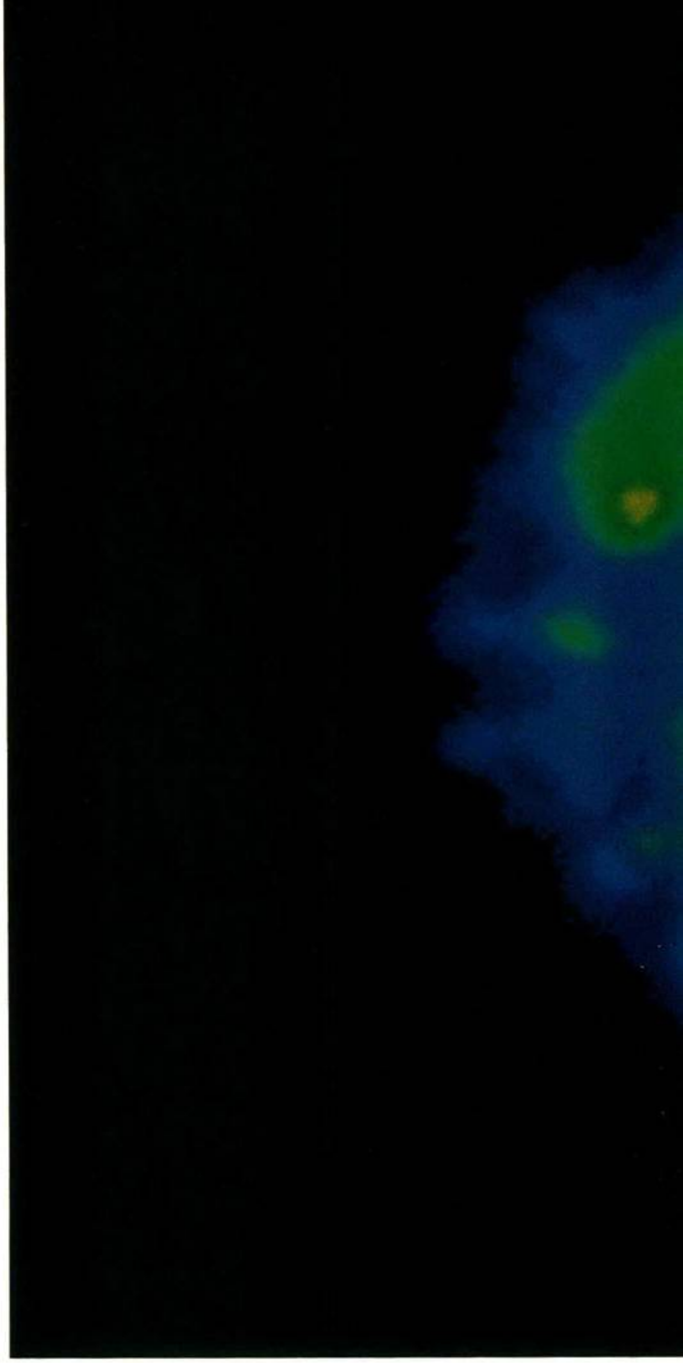








All images courtesy California Association for Research in Astronomy



Jerry Smith is quietly exultant. "Now that the instrument is fully operational, we'll be producing some exciting images." With these simple words, Smith, a staff member of the California Association for Research in Astronomy (CARA), reflected on the future of the Keck telescope, which workers completed on April 14, 1992. Now the world's largest optical telescope, the massive, $70-million instrument sports a segmented mirror that spans 33 feet (10 meters) and sits inside a bulbous, 100-foot-high dome atop Mauna Kea, Hawaii.

Astronomers expect that the Keck telescope will play a significant role in revolutionizing ground-based astronomy in both the optical and infrared parts of the spectrum. Among the research projects Keck will attack are imaging planets in orbit around nearby stars, studying the mechanics of star-forming regions, pinning down the existence of a supermassive black hole in our Galaxy, and working toward a theory of galaxy evolution. Not only is Keck by far the largest telescope — the previous record holder was the 6-meter Big Altazimuth Telescope in Russia — but with the possibility of adaptive optics it might outdo even the Hubble Space Telescope in all respects except coverage of the spectrum. Keck certainly is far ahead of all other Earth-based telescopes because of both its sheer size and its location, which may be the best observing site on the planet. And the W. M. Keck Foundation, the moving force behind the telescope, has pledged $74.6 million to build a second 10-meter scope, called Keck II, which will sit beside the original when it is completed several years from now.

Any way you look at it, the Keck telescope and its sibling will lead professional astronomy into the next century.

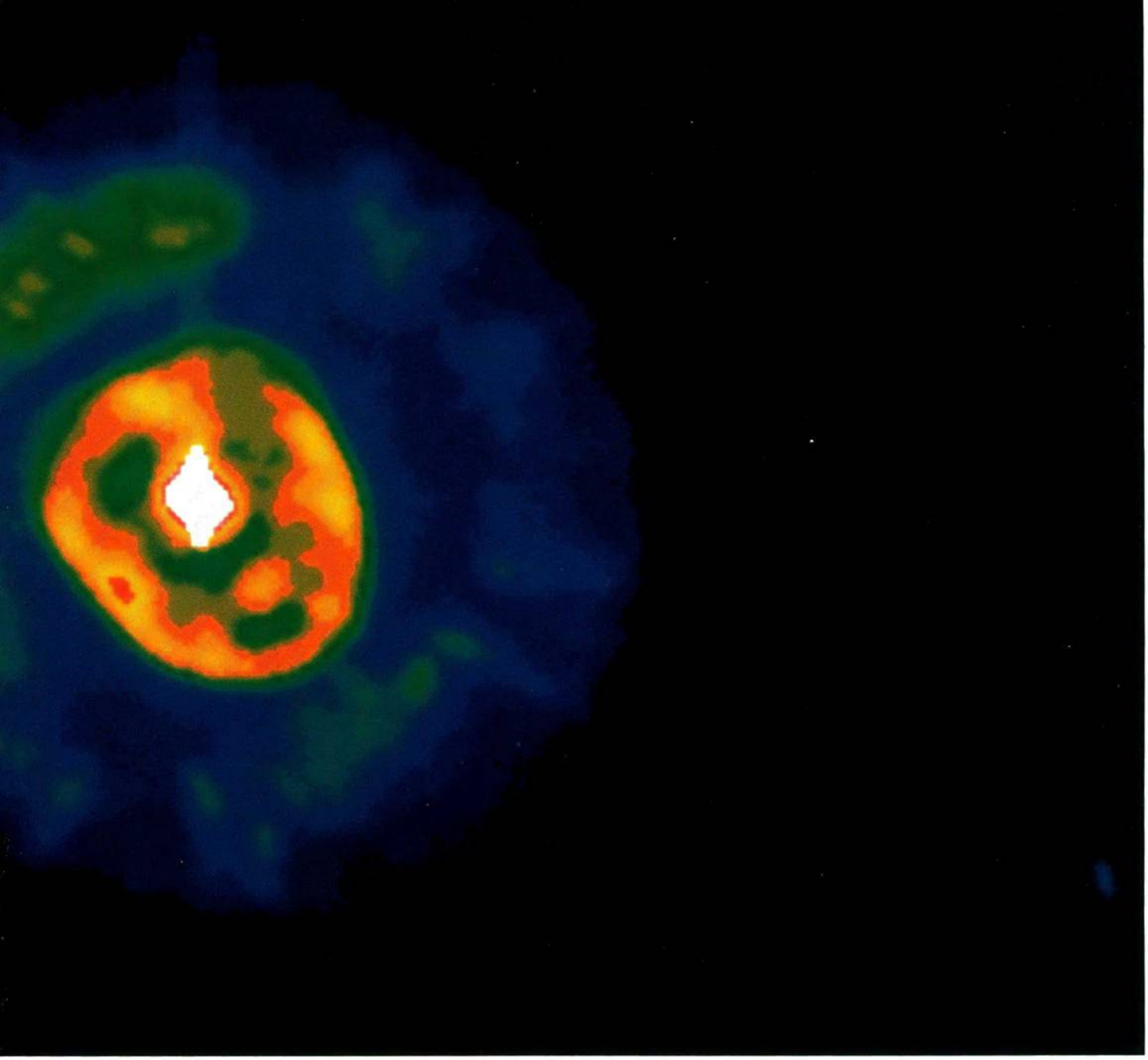
How Keck Came to Be

How did such a monumental project come to be? The history of the Keck telescope and CARA, its supporting organization, makes one of the most unusual stories in the annals of science. The story began long before any money entered the picture and long before any astronomers thought of placing the world's largest scope on Mauna Kea. "We started out in 1985 with a conceptual design in the basement of the West Bridge Physics building on the Caltech campus," says Smith. "Back then my secretary and I constituted the Keck telescope staff — a staff of two." Early on, Smith realized that to build a telescope on the scale of a Keck, he must investigate and ultimately employ some radically new technologies. These would have to be investigated, given trial runs, and work smoothly, even if the scope could be built for a relatively affordable $70 million. And then the search for the money would need to turn up some hefty backing.

To grasp the revolutionary nature of Keck, we need to return to 1985 to see the engineering problems then facing the project. Prior to the late 1980s, large telescopes had all been manufactured the same way, namely the primary mirror was cast as a single entity. This process is expensive, very tricky, and sometimes results in a less-than-perfect mirror. The 5-meter Hale telescope mirror, in use on Palomar Mountain since 1949, is such a monolithic mirror, and turned out very well. So is the Russian 6-meter mirror, which did not turn out well.

Producing a monolithic mirror involves the time-consuming steps of grinding as much as 60 percent of the mirror's surface away until the mirror is a parabola of the correct figure. In addition, technicians must constantly check the mirror to see that it conforms to the correct figure at each stage of the grinding and polishing processes. A 10-meter monolithic mirror faces not only these complexities but also other problems. The most important dilemma with big telescopes is that the bigger the mirror, the heavier and more unwieldy it becomes. Even with techniques that produce a thin or partly hollow mirror, a piece of glass larger than 4 meters across presents giant engineering problems in supporting the weight properly. A 10-meter mirror like Keck's would weigh in at 40 or 50 tons, making it simply too heavy if produced by conventional techniques.

That wasn't the only difficulty. Even if the engineers could overcome the weight problem, astronomers would have to cool down the telescope each night to the ambient air temperature outside the dome. Otherwise, distortion caused by waves of heat would blur the telescope's images. Because of the great thickness and density of a single chunk of glass, monolithic mirrors



THE KECK TELESCOPE reveals a ghostly face in this computer-enhanced, false-color image of the Eskimo Nebula in Gemini. Astronomers made this image and those on the following pages with 9 of the 36 mirror segments installed.

typically take hours to come down to temperature — some of them never fully equilibrate. Such is the case with the Russian 6-meter telescope, which shows chronic image problems in part because of an inability to reach thermal equilibrium.

As if these challenges weren't enough, the cash outlay required for a 10-meter monolithic mirror would have been, well, astronomical. Add to this the costs of building the telescope structure and the observatory, the scientific instruments used in conjunction with the telescope, and the ongoing expenses of maintenance and staffing, and the price tag for Keck would have soared into the $300- to $500-million range. That represents more money than anyone could pour into such a project.

All Is Not Lost

Jerry Smith, his secretary, and a slowly growing group of interested astronomers faced a rather challenging future. However, all was not lost. In the mid-1980s, a new wrinkle in mirror fabrication sprang up from the landscape. Roger Angel, Buddy Martin, and their colleagues at University of Arizona's Steward Observatory conceived the idea of spin-casting primary mirrors. This radically new process uses a rotating oven to melt large pieces of glass, typically E6 borosilicate, and spins the molten glass pile into a rough approximation of the desired shape. This process allows astronomers to produce thinner, much cheaper mirrors than the traditional method. After the blank cools, technicians give it a final figuring to the exact shape.

Another advance in mirror making, this time in the material used to form the blanks, came from the Schott Glassworks in Mainz, Germany. Schott conceived and then produced a glass-ceramic material, later named

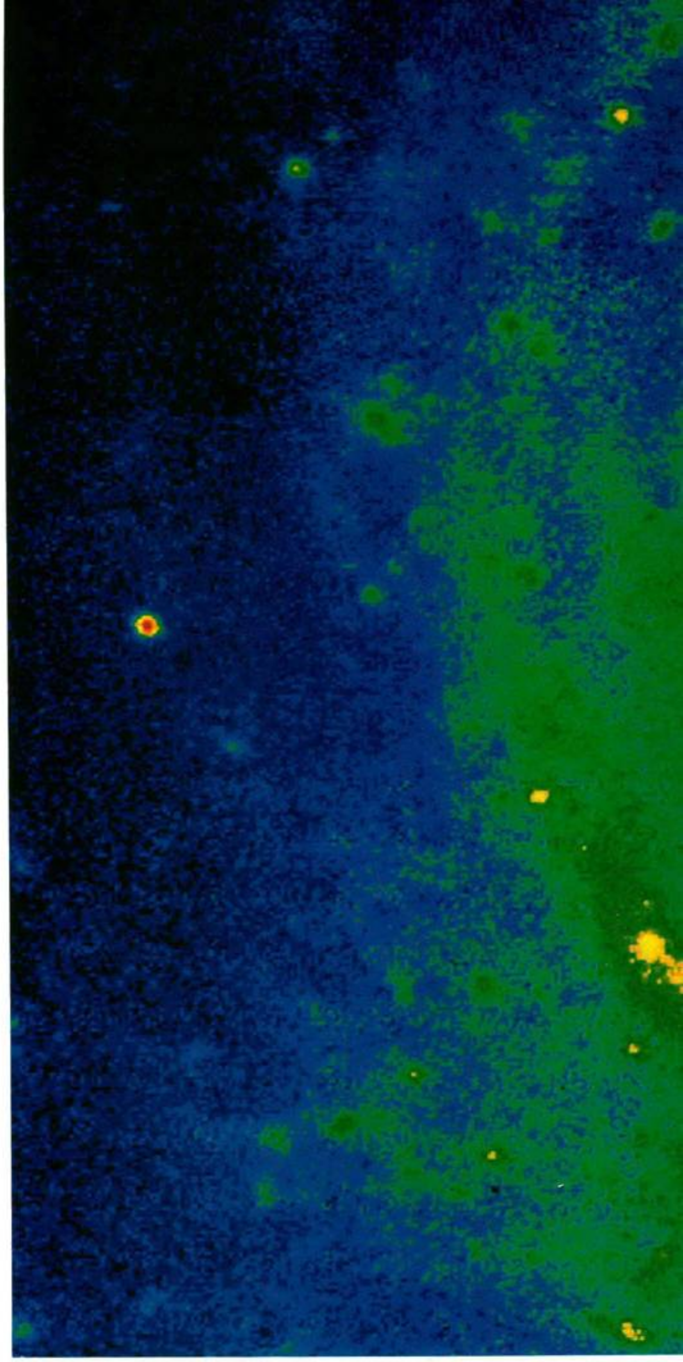
Zerodur. A composite, Zerodur combines two materials with positive and negative coefficients of thermal expansion. The result is that in environments of either increasing or decreasing temperature, the two components effectively cancel each other's thermal tendencies out to zero.

The concept ultimately chosen for Keck was another untried idea. The idea originated with Jerry Nelson, a young astronomer at the University of California at Berkeley. In 1977 a group of researchers at Berkeley set out to study the feasibility of constructing a next generation ground-based telescope. Nelson suggested the concept of a segmented mirror design. Says Smith: "People thought we were crazy to attempt to build such a telescope in the first place. When Jerry came up with the concept, there were many doubters." The critics had a point. Anyone who has ever tried to grind a telescope mirror knows it is an exacting, challenging task. But to construct a 10-meter mirror with dozens of individual segments, figure them to the correct shape, and keep them in perfect alignment while the telescope moves seemed overwhelming.

But the Berkeley group persisted. Engineer Jacob Lubliner worked with Nelson to come up with a solution to the mirror-figure problem. Nelson and Lubliner developed "stressed polishing," a method that would give each segment the correct off-axis shape once the piece was released from its grinding cell. Meanwhile, two scientists from Lawrence Livermore Laboratory worked with Nelson to reduce problems associated with the telescope's alignment. Terry Mast and George Gabor devised a method of using small sensors and actuators linked to a computer control system to align individual mirror segments within an accuracy of $^1/_{1,000,000}$ of an inch. After a great deal of preliminary work, in 1979 the astronomers presented the idea to a committee at the University of California. The university raised funds for ongoing telescope design and a technical demonstration using one complete mirror segment and a partial adjoining segment.

At the same time, scientists at the California Institute of Technology were studying concepts to augment the 5-meter Hale telescope on Palomar Mountain. After reviewing Nelson's work, Caltech decided to join the Berkeley effort. Smith says, "When this happened, there was some initial disappointment on the UC side, as the UC astronomers thought the entire program was theirs. Thankfully this feeling dissipated." Yet the two groups of astronomers needed plenty of money. The funding question was resolved when the W. M. Keck Foundation, a philanthropic organization based in southern California, agreed in late 1984 to provide some $70 million of the estimated $94 million needed to construct the telescope and its observatory.

With a workable telescope design and a large amount of money in store, the project needed an overall organization to oversee the progress on what became the Keck telescope. In 1985, members of the working group founded the California Association for Research in Astronomy (CARA), an organization consisting of two people. CARA's mission was to design, build, and operate the 10-meter telescope and to allocate time to various scientists submitting observing requests. CARA's staff grew to six board members, three each from Caltech and the University of California. Smith became project manager and Nelson chief project scientist. Smith tackled the challenge of enrolling other experts to oversee procurement, accounting, and design, and to begin the work of building the hardware. Says Smith: "Few people can appreciate the job it takes to accomplish this project. The most difficult part, I think, is going from the design to the execution phase. Within six months of CARA's establishment, design and fabrication activities were fully underway. We hit the ground running."



A Smooth Road Ahead

When construction on the Keck telescope began, few astronomers or engineers believed it could be assembled in five years. The mammoth scope of the project and its location on a 13,800-foot, dormant volcano seemed daunting. Yet the telescope was completed in five years, the building stage finished, and the testing stage underway.

"Throughout its history, Keck has been characterized by a strong spirit of support," says Smith. "This is particularly unusual because we have a collaboration

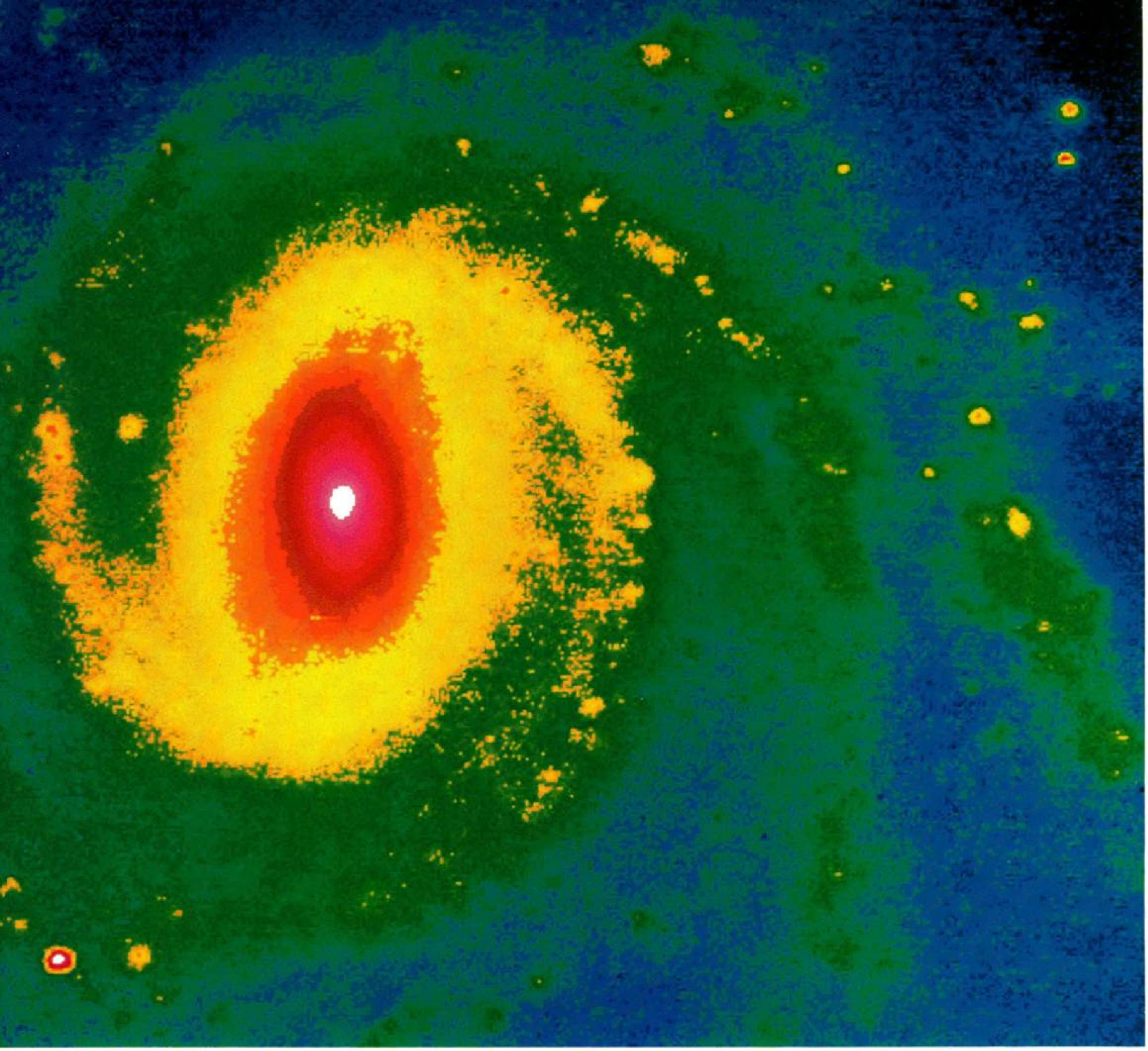


IMAGE ENHANCEMENT will enable astronomers to interpret photos made with the Keck telescope. In this image, galaxy NGC 1232's colors indicate increasing levels of surface brightness toward the massive galaxy's nucleus.

between a large, public university and a small, private college. Many opportunities arose for conflict of philosophies, but the team evaded those conflicts entirely." Smith believes the immediate availability of funds by the Keck Foundation ensured rapid progress. Other large telescope projects are currently having trouble raising funds in these hard times.

Most important, the astronomers' execution and coordination of Keck's mirror fabrication and observatory construction have gone very smoothly. "Our Science Advisory Group, consisting of a number of eminent advisors, has been the key to the success of the program," Smith feels. "They have lent scientific advice, offered hardware tradeoffs, and managed the development of our instruments and the observatory facility itself."

The management structure of the Keck project proved valuable. Smith notes that most major telescope projects are handled internally by universities. A faculty member supervises conceptualization, design, fabrication, and fund raising. This sets up problems, as most university faculty members have neither the time nor the working experience to head such a huge task. Results typically include years of delays and huge cost overruns.

Smith also credits Jerry Nelson for much of the project's success. "Jerry has been a major element in the success of the Keck telescope," he says. "As head of the Science Advisory Group during the procurement phase of the program, he provided tremendous assistance. Jerry has very high standards of performance and continues to push for better hardware and work standards."

Dream Becomes Reality

The last doubts slipped away on November 24, 1990. On that night astronomers made a "first light" image of the galaxy NGC 1232 in Eridanus and demonstrated the effectiveness of the segmented mirror design. Although astronomers made the first images using only nine of the mirror segments, the images were spectacular. In April 1992 technicians installed the final six mirror segments, so that all 36 are now in place. The construction phase of the Keck telescope is finished. The next steps in a year-long "shakedown" of the telescope before it attacks research projects at full speed include fully testing the secondary and tertiary mirrors, testing various devices that will be attached to the telescope, and integrating and testing scientific instruments that will analyze the Keck data.

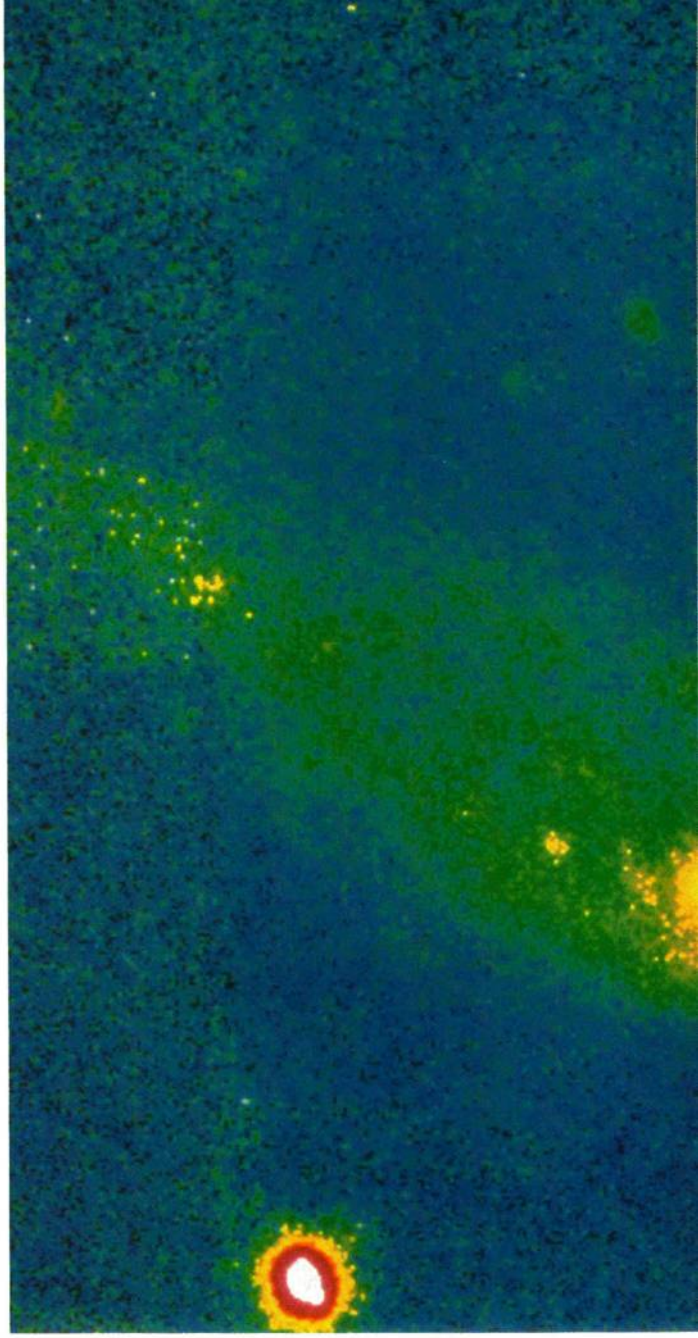
Keck's research instruments include a near infrared camera, a low-resolution imaging spectrograph, a long-wavelength infrared camera, a high-resolution spectrograph, and a low-resolution spectrometer. Current plans are that once the infrared cameras are commissioned, time will be allocated for research. The first recipients of this time are likely to be astronomers from the University of California and Caltech. Observing time also will be granted to the University of Hawaii, as it donated the site for the observatory on Mauna Kea. The earliest projected date for these initial investigations is autumn 1992.

The quality of data returned from Keck when the telescope is fully used will be remarkable. Chiefly this is due to the high quality of the optics. Project manager Smith says that while the mirrors were somewhat below the goals first set by ITEK corporation, the firm charged with figuring the segments, they are excellent optics. Testing indicates that of all the incident light on any single mirror surface, 80 percent fits within a 0.25-arcsecond-diameter circle. This translates to a mirror surface of about $^{1}/_{50}$ wave accuracy.

Six spare mirror segments — and eventually the installed segments — promise to be figured to even finer tolerances, as they are being polished using a new technique known as "ion figuring," developed by Eastman Kodak. This technology directs a beam of ions at the surface of the low-expansion Zerodur glass. The process knocks off glass molecules in a precise, controlled manner. By employing a computer programmed for the desired shape, and by constantly rechecking for errors in that figure, technicians can produce a virtually perfect surface. The only limitation that remains is the accuracy with which the mirror surface can be tested.

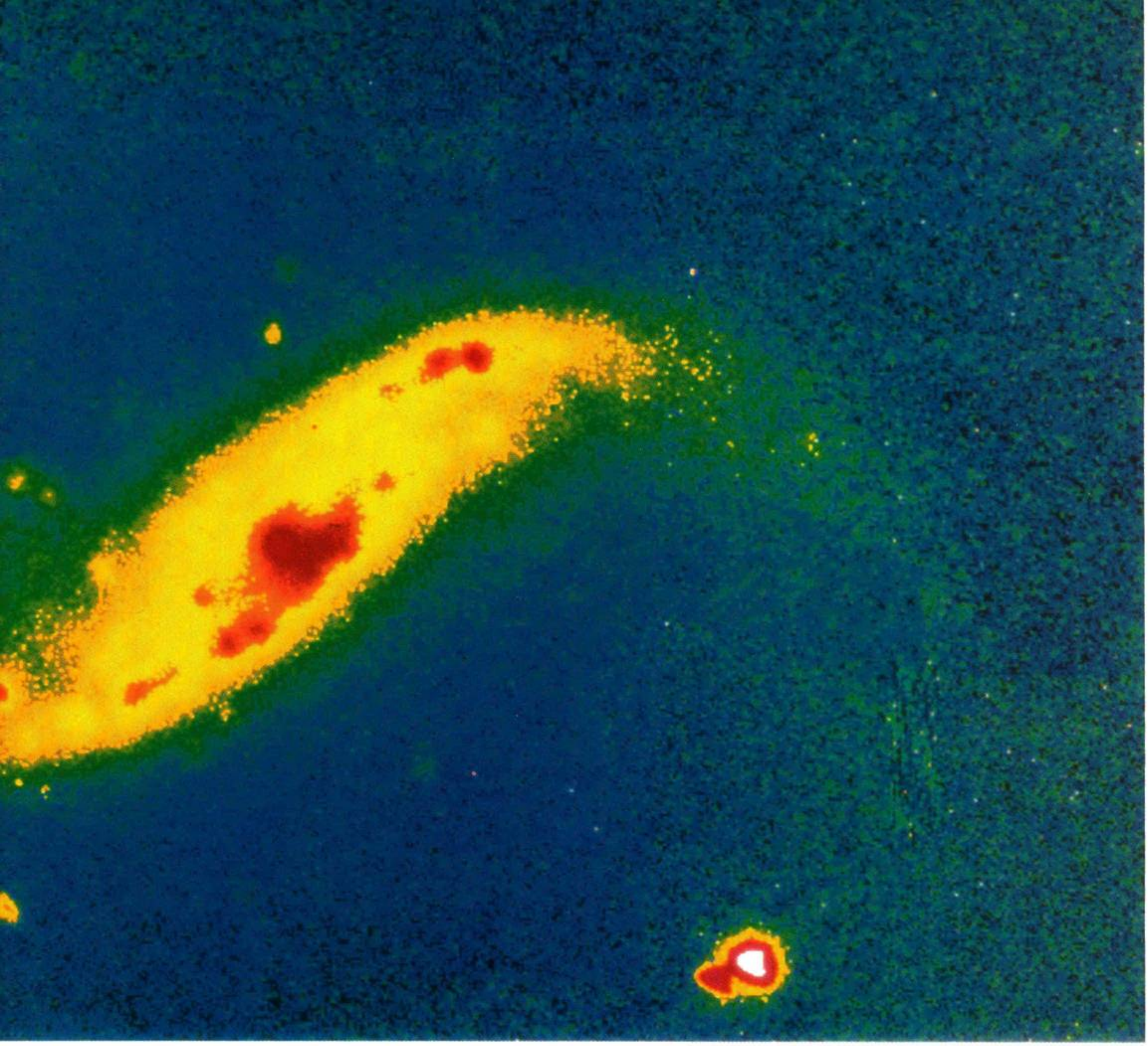
Keck Begins its Research

Keck will be used primarily as an infrared telescope because of its lofty position above much of Earth's layer of water vapor. Keck scientists will not neglect visible light research, however. "We may occasionally use the visible-wavelength capability to demonstrate the full potential of the hardware," says Smith. The quality of the visible light images, like those of the Eskimo Nebula (NGC 2392) in Gemini and galaxy NGC 3187, are stunning — and they were made with just nine of the 36 mirror segments in place. The most likely targets for Keck will be faint, cool infrared objects near the limits of current instruments. Galaxies with significant protostar populations, active star-forming regions like those theorized to exist in M42, and suspected extrasolar protoplanetary disks are candidates for early research.



And what of the future? Keck II, an identical twin of Keck I, is already underway. Keck II is scheduled for completion in 1996, at a total project cost of $93.3 million. As with Keck I, the second telescope's major funding will be provided by the Keck Foundation. Plans call for the second telescope to be located 250 feet from the first. At a press conference at Caltech in mid-1991, Keck Foundation president and chief executive officer Howard B. Keck said, "The technological breakthroughs achieved with the construction of the first Keck telescope have encouraged us to push further the boundaries of astronomical research that will only be possible with a second telescope. We also hope that the exciting discoveries made possible by these two telescopes will motivate more American students to pursue careers in science and technology."

Using interferometric techniques, the two 10-meter instruments will eventually be combined to form an 85-meter-aperture telescope. Project manager Smith envisions the final configuration for Mauna Kea's Keck



THE DISTURBED SPIRAL GALAXY NGC 3187 reveals evidence of gravitational interaction in this false-color Keck telescope image. Astronomers will use the instrument to research galaxies like NGC 3187 over years to come.

facility as follows: "Two twin 10-meter segmented telescopes, supported by four or five additional telescopes in the 1- to 2-meter-aperture class, all interferometrically joined together."

Edward Stone, director of NASA's Jet Propulsion Laboratory and vice president of the CARA board of directors, is extremely excited. "The construction of a second Keck telescope will result in an observatory with an unparalleled combination of light-gathering power and 10 to 100 times better spatial resolution," Stone remarks. "The detail these telescopes will be able to discern will be comparable to separating a car's headlights from a distance of 16,000 miles." Stone adds, "The two Keck telescopes, operating together as an infrared interferometer, would have the power to identify the presence of warm, Jupiter-sized bodies in orbit around the 100 nearest stars." Smith is also very optimistic. "We have a distinct advantage, being a ground-based system. You can push the limits of technology very hard with hardware like Keck," he says. "Certainly you take risks in doing so. But that's one of the reasons to develop the technology to begin with."

Even with the risks CARA is taking, the coming years promise to provide a bountiful scientific payoff for the unprecedented $145 million investment the Keck Foundation has made. As I stood in the thin, cold air beside the dome of the Keck telescope recently, I felt the winds of change blowing. A new era of astronomy is here. □

Joel K. Harris is a science writer living in Burbank, California. His last article was "Travel Tips for the Big Eclipse" (June 1991).

NEAR-EARTH OBJECTS

INTERPLANETARY FUGITIVES

Earth-approaching asteroids and dead comets that formed elsewhere in the solar system give astronomers a glimpse at our origins.

by Lucy-Ann McFadden and Clark R. Chapman

Michael Carroll

Our planet travels among a swarm of small rocky bodies only a few yards to a few miles across. Most of these asteroids pass Earth at high speed millions of miles away. But on occasion, a few come much closer. These encounters pose both a danger and an opportunity. They may produce a catastrophic collision someday, but in the meantime they have given astronomers the best look yet at objects that are highly important to the understanding of the solar system's past.

The Sun and planets formed from a great swirling cloud of gas and dust $4^1/_2$ billion years ago, leaving behind debris consisting of gas, dust, and small bodies. The newly formed planets quickly swept up the debris near their orbits. But in between the planets — and beyond Neptune — there were great swarms of small bodies that never became incorporated into planets or satellites.

The small bodies in the inner solar system contained mostly rock and metal. Those in the outer solar system contained mostly ices and dark, carbon-based compounds. As the solar system aged, most of the debris between the orbits of Mercury, Venus, Earth, and Mars either smashed into one of those planets or escaped from the inner solar system after encountering the gravitational field of one of the planets. One great reservoir — the asteroid belt — remains in the wide gap between Mars and Jupiter.

In the outer solar system, small, icy bodies were stranded in stable reservoirs beyond the orbit of Neptune. The most famous reservoir is the Oort cloud, from which long-period comets visit the solar system. Closer to Neptune is the Kuiper comet belt, a source of numerous short-period comets. Although many of the small objects between the outer planets have collided with a planet or escaped, some of these icy bodies still orbit slowly around the Sun.

The small-body reservoirs (asteroid belt and comet clouds) have lasted the age of the solar system. Some of the bodies in these vast reservoirs leak out and come whizzing by Earth. The most spectacular, of course, are the new comets that appear every few years. They are short-lived celestial visitors, rapidly losing their frozen gases in the heat of the Sun. The loss of dust and ice reduces comets to inactive lumps of rocky residue after only a few thousand years in the inner solar system.

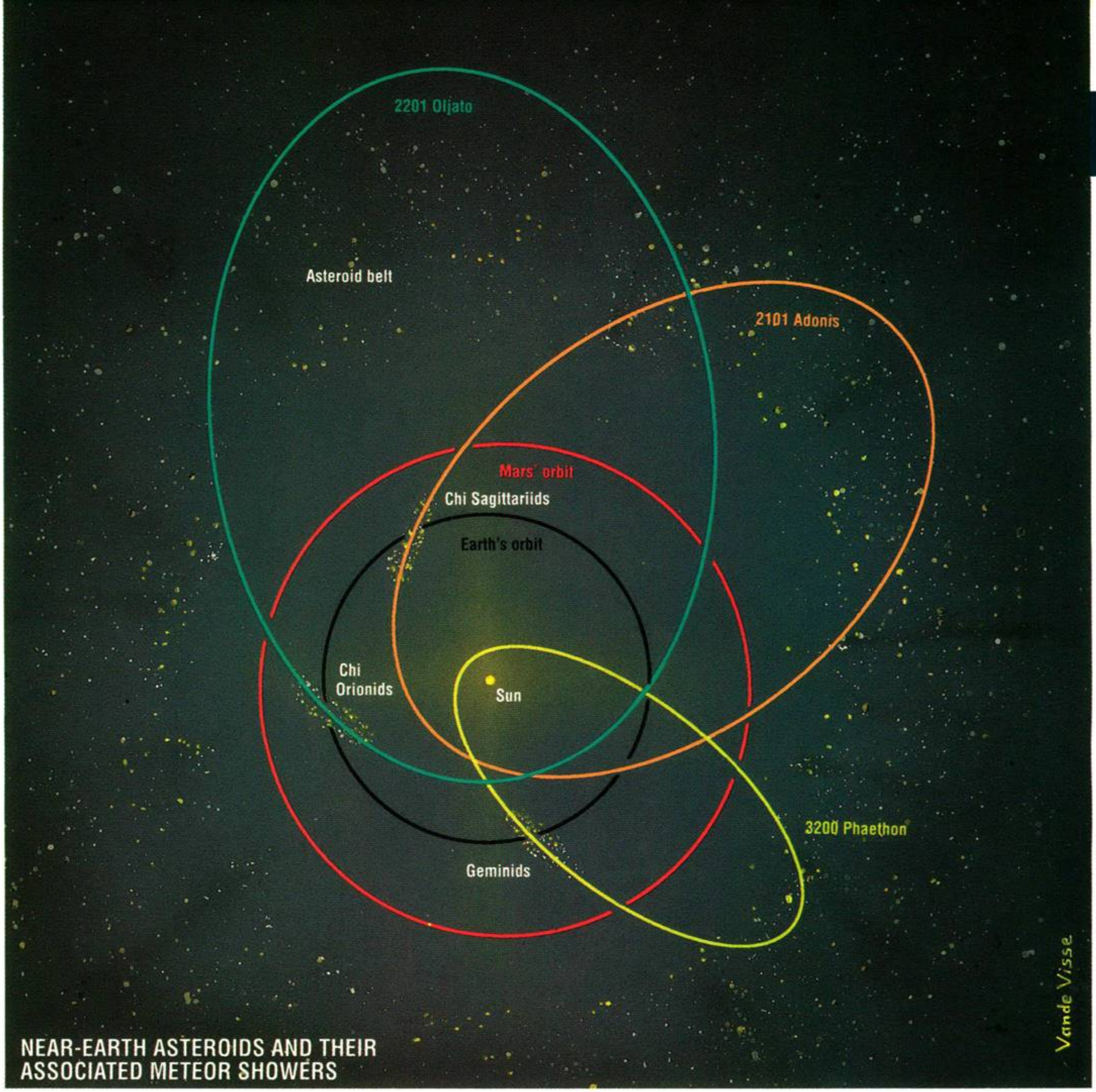
The biggest and most numerous of the bodies that pass close by our planet are dead cometary remnants and fragments from the asteroid belt that strayed into Earth's territory. Neither dead comets nor asteroids give off long, glowing tails as new comets do, which makes them difficult to see. But every couple of years, a small object — such as the 300-meter-diameter asteroid 4581 Asclepius seen in March 1989 — passes within twice the distance to the Moon. About every 100,000 years, a 1-kilometer-wide object collides with Earth, with devastating results. And every 50 million years or so, a 10-km-wide asteroid hits with such catastrophic force that it endangers life on the surface of our planet. Such an impact may have caused the demise of the dinosaurs and many other species 65 million years ago.

Astronomers estimate that between 1,500 and 2,000 asteroids and dead comets with diameters ranging between 1 km and 40 km are in Earth-approaching orbits. Only a small fraction of them will strike Earth someday. Others will collide with Venus, the Moon, or Mars. But the majority will move into larger orbits or will leave the solar system altogether.

While some Earth-approachers break away from the population and never threaten us again, others come in. The distant Oort cloud and the Kuiper belt provide fresh comets that visit the inner solar system. There the Sun's gravity traps some of them and they lose their ices during a few millennia of glory. The comet remnant then joins the ranks of cometary corpses, which account for up to a third of all near-Earth objects (NEOs).

Comets aren't the only fugitives that visit the inner solar system. Objects in the asteroid belt collide and break into fragments. Erratic orbital changes drive some of those fragments into elongated orbits that stretch inward, across the orbit of Mars and perhaps the orbits of Earth and Venus.

A typical member of the NEO population lingers in the inner solar system between 10 and 100 million years. Though individual members of this population may come and go, Earth always has resided in an



NEAR-EARTH ASTEROIDS AND THEIR ASSOCIATED METEOR SHOWERS

ASTRONOMY: Illustrations by Lee Vande Visse

asteroid swarm and will continue to do so for billions of years to come.

Earth-approachers are small by planetary standards, and most of the time they are far away — tens of millions of kilometers. Their small sizes and large distances from Earth make it difficult for astronomers to see them. In fact, of the estimated 1,500 to 2,000 objects larger than 1 km across, astronomers have found fewer than 200 of them and some of these can no longer be located. Little is known about most of them: For over 100 of them, astronomers know only the shapes of their orbits and their approximate brightnesses. Information about their sizes, shapes, rotation periods, colors, and compositions is known for fewer than 50 NEOs.

NEOs are important because their composition tells about the material from which our solar system formed. The difference in composition between various types of NEOs indicates how material was spread through the solar system while it formed. The orbits of these objects hint at how debris escaped from the solar system after the planets formed. But to learn more about these objects and where they came from, astronomers need to observe more of them.

Search and Discovery

Every month for two weeks during the dark of the Moon, teams of scientists scan the skies for unknown asteroids that cross or approach Earth's orbit. Two teams take turns observing at the 46-centimeter-diameter Schmidt telescope atop Palomar Mountain, 50 miles northeast of San Diego, California. One team, led by Eleanor "Glo" Helin, drives down to Palomar from the Jet Propulsion Lab in Pasadena. The other team, consisting of Gene and Carolyn Shoemaker, drives from Flagstaff, Arizona, where they work at the U.S. Geological Survey. Both groups systematically search the sky for faint, fast-moving objects.

Before leaving Pasadena, Helin checks the list of

HIGHLY ELLIPTICAL ORBITS take the near-Earth asteroids and their associated meteor streams along a path from the asteroid belt to inside Earth's orbit.

known NEOs for those with poorly determined orbits to see if they are observable on her observing nights. She maps out the sky fields her team will photograph, each field representing a patch of sky 9 degrees across. At the telescope, the team photographs each patch, using a 10-minute exposure. After about eight exposures, one team member develops the photographic plates while another loads more plates into the holder and decides where to point the telescope next.

After two plates are developed and dried, the NEO search begins at the stereomicroscope. Helin views pairs of plates taken of the same region. Slightly displacing the film pairs relative to each other enhances the apparent motion of a fast-moving object.

After the team grabs a few hours of post-dawn sleep, the plate scanning continues at the stereomicroscope. Helin notes any moving objects and compares this list with the asteroid ephemeris, a book of the positions of all known asteroids. Previously known asteroids receive no more attention.

The objects Helin can't find in the ephemeris are possible discoveries. She determines their positions relative to nearby stars and sends a message to the Central Bureau for Astronomical Telegrams, operated by the International Astronomical Union (IAU). Astronomers at the bureau in Cambridge, Massachusetts, confirm whether the object is in fact a new asteroid.

A new object is given a temporary designation that contains the year, the half-month, and the order of discovery in that period. For example, 1992 PD would be the fourth object (D) discovered in the first half of August (P; I is not used) of 1992. Observation of the asteroid at two oppositions and the determination of an accurate orbit entitles the asteroid to a permanent number. The discoverer may name the object, subject to the approval of the IAU. So 1978 SB became 2212 Hephaistos but 1983 SN was not named because it was lost to view.

BETWEEN 1,500 TO 2,000 ASTEROIDS AND DEAD COMETS ROAM SPACE NEAR EARTH

The friendly competition between the Helin and Shoemaker teams, augmented by recent searches by the Spacewatch telescope in Arizona and teams in Australia and elsewhere, has pushed the discovery rate higher each year. For example, during the 1970s only a few NEOs were discovered each year, but several dozen were found in 1991. New technology helps increase the number of discoveries. For example, CCD (charge-coupled device) cameras replace photographic plates at the University of Arizona Spacewatch program. The fainter magnitudes reached by this program enable it on average to find two new NEOs each month.

Upon discovery of a new asteroid, an informal network alerts all observers who might be able to follow the object's motion. These follow-up observations during the next few nights are necessary to obtain enough positions to accurately determine an orbit. From these observations, astronomers at the Central Bureau office compute a preliminary orbit of the asteroid, which is announced on an IAU Circular. This orbit tells other astronomers where they can find the object so they can try to determine the asteroid's size, shape, color, and composition.

Physical Properties of NEOs

Most NEOs appear slightly reddish in color and reflect about 15 to 20 percent of the sunlight that shines on them. They are like the asteroids in the inner edge of the asteroid belt. This leads astronomers to suspect that many NEOs came from this inner region. But there are a few NEOs with colors that are not commonly found among the objects in the asteroid belt. 1862 Apollo is one such near-Earth asteroid that has the color and spectral properties of ordinary chondrites, the most frequently found meteorites on Earth. Rare among the discovered NEOs are dark bodies, but there is a bias against finding them because they are so black. Even rarer are bright, reflective objects and objects composed mostly of metal.

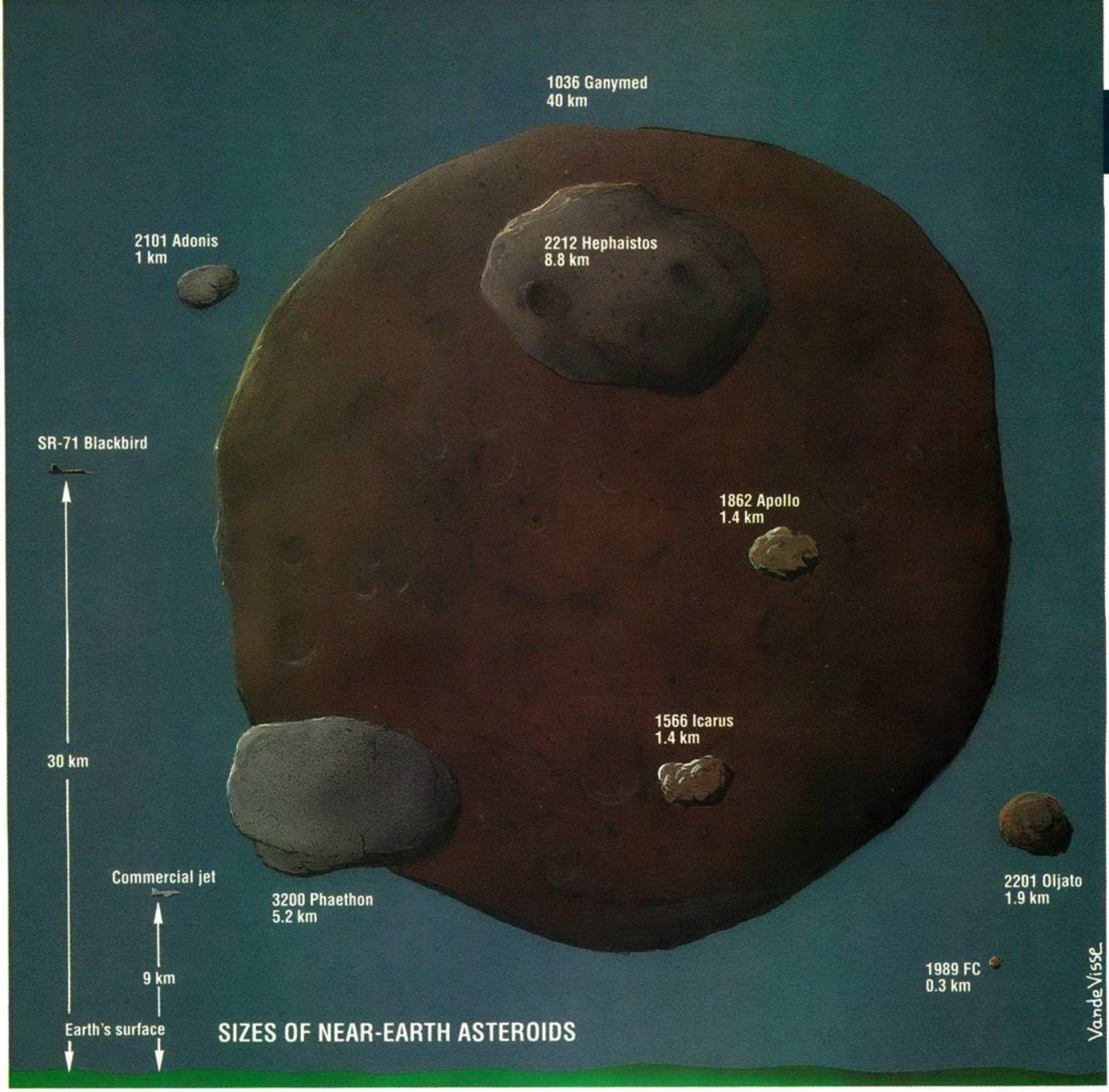
From the ratio of an object's reflected visible light to its heat radiation, astronomers can determine an asteroid's size and reflectivity, even though they can't see its surface directly because of its starlike appearance. The less light it reflects, the hotter it becomes and the more heat it radiates, compared with a more reflective and cooler body. From its total brightness, astronomers can then calculate the object's diameter.

The largest NEO (1036 Ganymed) is about 40 km in diameter. The smallest one discovered with a telescope so far is just 5 m by 10 m in size. More typical sizes of discovered NEOs are between 0.5 km and 10 km in diameter, but that probably says more about our search techniques than what's really out there: sampling statistics suggest that there are large numbers of smaller objects.

Periodic changes in the brightness of the object establish the NEO's rotation period. Astronomers wonder about a few NEOs that spin very slowly. While most rotate once every 3 to 10 hours, the asteroid designated 3102 1981 QA (the discoverer has not yet given this asteroid a proper name), takes more than six Earth-days to rotate once. 1566 Icarus, which has an orbit that takes it inside that of Mercury, is among the fastest rotating NEOs. Rotating once every 2.2 hours, it is on the verge of breaking apart because it spins so fast. Possibly their asteroidal or cometary origins explain the difference between the fast-spinning NEOs and the lazy ones that hardly spin at all.

In order to assess an NEO's mineral composition, observers measure how much sunlight it absorbs at different wavelengths. Certain rocks have a characteristic spectral fingerprint. We know that the composition of these cosmic interlopers is similar to the basic mineral building blocks that make up the planets and satellites in the solar system. Some NEOs are almost entirely metallic. Others contain mostly organic-rich clays that would probably fall apart if you picked them up with your bare hand. Still others are igneous rocks, fragments from a once-molten small planet.

Astronomers can study the closest NEOs by bouncing radar beams off their surfaces. From a radar echo, they can determine the position of the object with



SIZES OF NEAR-EARTH ASTEROIDS

exceptional precision. A rotating object smears the finely tuned radar pulse into a number of echo frequencies, with a broad radar echo indicating a fast rotator. And the shape of the returning radar pulse indicates whether the object has a smooth surface or craters, hills, and valleys.

As astronomers piece together information about the sizes, shapes, and compositions of NEOs, they learn about the history and origin of the solar system. The orbits and physical properties of NEOs tell researchers where these objects came from. The orbits also suggest relationships among different types of objects.

Relationships to Meteors, Meteorites, and Comets

The known NEOs are just the largest members of a whole complex of mostly smaller interplanetary particles that can be microscopic in size. The smallest particles that fall into Earth's atmosphere often survive their flight through the atmosphere. These tiny meteorites, called Brownlee particles, add tons of dust every year to the stratosphere, polar ice caps, and ocean sediments. Larger particles about the size of sand grains or apple seeds flame to their death in a brief burst of light as meteors. You can see them any night in a clear dark sky.

Typical meteors disintegrate tens of kilometers up in the atmosphere and never reach the ground. But the most brilliant fireballs may make it to the ground as fist-sized meteorites, especially if they contain hard rock or metal. But between the small particles that become meteors and the size of the smallest known NEOs, the interplanetary debris is presently unobservable.

Astronomers believe that nearly all interplanetary debris comes from disintegrating comets or chips broken off asteroids by collision, or from material ejected from craters formed when small asteroids or comets impact larger ones. Some comets have spawned specific meteor showers: the Eta Aquarid and Orionid meteor showers are debris left behind by Comet

NEAR-EARTH ASTEROIDS ARE LARGE by terrestrial standards, comparable to the size of cities. The colors of asteroids hint at their rocky or icy composition.

Halley, while Comet Giacobini-Zinner gave birth to October's Draconids.

Many meteor showers have no known comet associated with them and most comets have no known meteor shower association. But this may change as astronomers discover more NEOs. 2101 Adonis may be the parent body of the Chi Sagittariid, Scorpiid-Sagittariid, and Capricornid-Sagittariid meteor showers, since they all travel in the same orbit. Likewise, 2201 Oljato and the southern Chi Orionids are related. In 1983, the Infrared Astronomical Satellite discovered 3200 Phaethon. The asteroid follows the same orbit as the Geminid meteor shower, indicating that asteroids as well as comets can be the parent body of debris in a meteor stream. (Phaethon has the most elliptical orbit and approaches the Sun more closely than any other asteroid.)

However, the identity of this debris as ejecta from a now-inactive comet or as the product of an asteroid-asteroid collision is still in question. Recently, Jack Drummond, a New Mexico astronomer, looked at how closely the orbital elements of the near-Earth asteroids resembled each other. He found three groups with such similar orbits that they would qualify as a meteor stream if the orbits were of meteors instead of asteroids. Then he read the results of Ian Halliday, a Canadian astronomer who calculated the orbits of fireballs photographed by a Canadian camera network. To his surprise, three of the groups that Halliday discovered coincide with Drummond's three groups of NEO orbits. The existence of asteroid streams seems to support the theory that at least some meteor streams are the product of asteroid-asteroid collisions. These collisions must have occurred within the last few thousand years, otherwise the debris would have dispersed beyond our ability to recognize any orbital association.

ASTRONOMERS NOW BELIEVE THERE IS LITTLE DIFFERENCE BETWEEN COMETS AND ASTEROIDS

Dead Comets Versus Asteroids

Some of the NEOs hurtling through space are really dead comets. But one problem is recognizing which ones are comets and which ones are the presumably more common fragments of asteroids. One clue is the object's orbit. A highly elliptical or highly inclined orbit is more likely a comet. Hephaistos has an orbit similar to that of Comet Encke, so it is probably a dead comet. Computer modeling of the history of Oljato's highly elliptical orbit traces it back to a more cometlike orbit having chaotic swings in orbital radius due to multiple tugs by Venus and Earth.

Astronomers have studied the physical properties of some of these inactive comets masquerading as asteroids. Radar echoes from Adonis, for example, are different than those from normal, rocky asteroids. Oljato showed an excess of ultraviolet radiation, which might have been the signature of outgassing water. Confusing Oljato's identification is its high reflectivity, or albedo. It reflects 30 to 40 percent of the sunlight hitting it. Its reflectivity is much higher than that of most comets and is high even for the bright objects of the asteroid belt.

3552 Don Quixote and 1984 BC are very red and dark and have cometlike orbits. These objects appear similar to bodies found in the outer edge of the asteroid belt. These outer belt asteroids may have cometlike compositions, thus making the distinction between comets and asteroids somewhat blurry.

Fragments and crater ejecta from kilometer-wide NEOs may become meteorites that occasionally hit the ground. Laboratory studies of the colors and chemistry of meteorites compared with NEO spectra may indicate which NEOs produce which types of meteorites. Almost all of the meteorite types match objects observed in the near-Earth population. In addition, one of the best candidates for the last parent body of some ordinary chondrites is Apollo. This was the first Earth-crossing asteroid found, thereby giving its name to the whole group of objects with Earth-crossing orbits. However, Apollo's true nature remains a mystery. No object yet observed in the asteroid belt has the color or spectrum of Apollo. But the thermally changed minerals in ordinary chondrites make it unlikely that the parent, Apollo, is a dead comet.

Spectrally, 1915 Quetzalcoatl resembles particularly rare meteorites called diogenites, which have been heated to their melting point and slowly cooled. The third largest asteroid in the main belt, 4 Vesta, apparently has a similar composition, with lava basalts on its surface, but it is difficult for fragments from this body to stray into an Earth-crossing orbit — a large change in energy would be required. But perhaps these fragments have strayed after all, because Quetzalcoatl is in a gravitational resonance with Jupiter.

Recently, researchers found what appears to be a metallic asteroid, 1986 DA. We know its composition from its color and the almost total reflection of radar signals. There are also a few objects containing carbon compounds flying around in space, but they are hard to see because they are very dark. As we discover and study more of our rocky neighbors, we find additional counterparts to the meteorites that we have in our Earth-bound collections.

Astronomers used to think that nearly all of the smallest particles in the inner solar system were cometary dust. Now they know that asteroids also contribute a large share. The distinction between comet and asteroid has become more uncertain, perhaps one of nomenclature rather than physical reality. Many an asteroid might have once had a cometary tail. And studies may underplay the significance of comets' rocky compounds simply because they are inherently less visible.

Together, the comets, asteroids, and smaller pieces that stray into the orbital path of our planet are our nearest neighbors in space. And as remnants from the earliest epoch of solar system history, they will teach us about our origins. □

Lucy-Ann McFadden is a planetary scientist at the California Space Institute of the University of California, San Diego. Clark R. Chapman is a planetary scientist at the Planetary Science Institute in Tucson, Arizona.

VOLCANIC TWILIGHTS

Eruptions of volcanoes half a world away can produce vividly colored sunsets visible from your own back yard.

by Alister Ling

FIERY RED SUNSETS, such as this one seen over Tucson, Arizona, were the norm through late 1991 and early 1992, a result of Mt. Pinatubo's eruption in June 1991.

William Livingston

Sunsets colored with flaming reds and delicate purples, and a night sky fogged by wispy clouds of ash — these were the side effects produced by the devastating volcanic eruption of Mt. Pinatubo in the Philippines in June 1991.

For most people, the scenes of destruction, raining ash, and the relocation of people and homes faded from memory in a few weeks. But for astronomers around the world, the skies were about to be invaded. During the fall and winter of 1991/92, Pinatubo's spreading ash clouds engulfed much of Earth's atmosphere. While the effects went unnoticed by most people, astronomers couldn't help but notice.

The night skies over the world's observatories lost much of their pristine clarity. Skies normally black at the darkest observing sites appeared gray. The faintest stars were blotted out by the haze of Pinatubo's high-altitude ash clouds. Even normally deep-blue daytime skies turned milky white.

Although astronomers cursed Pinatubo's legacy, casual skygazers delighted in the twilight show the volcano created. As had happened after previous volcanic eruptions, Pinatubo repainted the evening and morning skies with a new artist's palette of reds, golds, and purples. The effects are now diminishing, but it's still worth keeping an eye on the twilight sky.

A Rainbow Sunset

When the atmosphere is free of volcanic dust, the usual palette of twilight colors just after sunset (or just before sunrise) looks like this: the deep-blue vault overhead gradually lightens, as we shift our gaze toward the horizon, and turns a pale white or light green. Just above the horizon, the sky appears yellow, with deepening shades of orange or perhaps pale red rimming the horizon. As the sunset progresses, the green disappears to leave only the dark blue above and a thinning horizon wedge of deep orange. If the atmosphere is very clear, some of the shades can be quite vivid.

These colors are the result of sunlight's being scattered by air molecules and dust particles. All wavelengths of light are scattered, with blue scattered the most and red the least. Compared to a noonday Sun, the light from a setting or rising Sun has to travel through much more air, which increases the scattering. The normal twilight sky follows a rainbow sequence from zenith to horizon as the blue, green, and yellow colors are progressively scattered by the progressively thicker layers of atmosphere.

An Angry Sky

Volcanoes complicate the process by occasionally injecting tons of ash, gases, and sulfur high into the atmosphere. As it did after Pinatubo's eruption, material from explosive volcanoes ends up in a layer confined to an altitude of 70,000 feet, placing it high in the stratosphere and well above the layer where normal weather takes place.

To put this altitude in perspective, low-lying clouds are about 2,500 feet up, wispy cirrus forms near 35,000 feet (the same altitude jet airliners typically travel), and the tallest and most violent thunderstorms tower no higher than 50,000 feet. Volcanoes obviously pack quite a punch to propel material up as high as 70,000 feet.

Once in the stratosphere, the sulfur reacts with ozone and hydrogen to form tiny sulfuric acid droplets. The ash from the pulverized rock actually turns out to be only a small percentage of the particles suspended in the air — most of the twilight-affecting material is sulfuric acid.

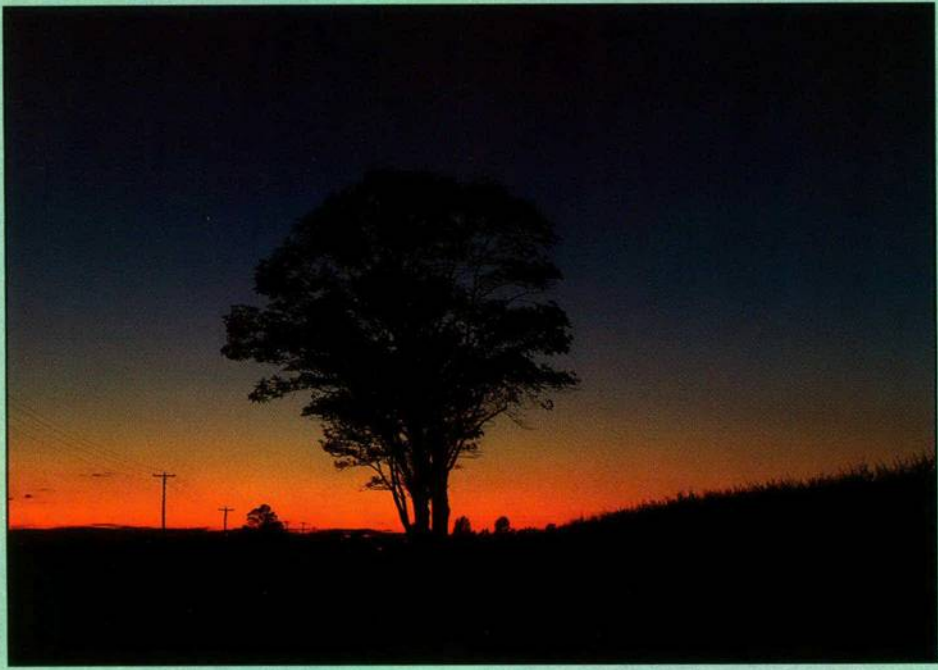
The sulfuric acid droplets, or aerosols, are much smaller than ordinary dust — only 0.002 millimeter across — and are easily transported around the world by the high-altitude jet streams. These air currents meander far to the north and south, ensuring that people living even as far north as Alaska can witness volcanic sunsets.

It may take a few days or weeks for the material to spread around the world, but not long after a major eruption, avid skywatchers can tell something just "doesn't look right."

During the day the sky is light yellow or almost white up to 30 degrees above the horizon. Even after the Sun has set and low-altitude clouds are dark, the background sky looks like a bright sheet filled with subtle waves, ripples, or streaks. These are the ash clouds catching the sunlight at their high altitudes. Sometimes thicker parts of the volcanic clouds cast their shadows onto the thinner ones, producing dark waves instead of bright ones. Often the sky looks just plain "dirty."

As a volcanic sunset progresses, a distinct purple band develops between the whitewashed blue above and the now gold sky below. The purple gradually broadens as the bottom edge of the purple zone lowers. The intense gold and orange horizon glow can be far more vivid than during a normal sunset.

A NORMAL SUNSET



Alister Ling

If the sky is cloudless at sunset you'll often see a subtle rainbow sequence of colors in the western sky. Blue high in the west fades to a delicate band of green, which blends into a yellow-gold. Orange and red rim the horizon.

The sequence of colors arises because as you look closer to the horizon you are looking through a deeper cross-section of Earth's atmosphere. Only red light can penetrate through such a long path without being scattered. Higher in the sky, shorter wavelength yellow makes it through. For sunlight taking the shortest path through the atmosphere only blue light is scattered around the sky, making the sky look blue.

You can demonstrate the same effect in your kitchen. Add a teaspoon of milk to a glass of water and then hold the glass up to the Sun. The mixture looks blue when viewed from the side — blue light is being scattered out — while the Sun looks orange when viewed through the glass. If you keep adding milk (simulating the effect of light passing through more atmosphere), the Sun will turn deep red, just as it does on the horizon.

A VOLCANIC SUNSET

The classic colorful sunset that most people picture occurs when the western sky is partly cloudy. The low-lying clouds reflect the red light of the setting Sun and produce a colorful sunset.

But volcanic sunsets are different. They occur when a volcanic eruption injects a layer of haze high in the atmosphere. To see the full effect, you need a perfectly cloudless sky, both near you and far to the west.

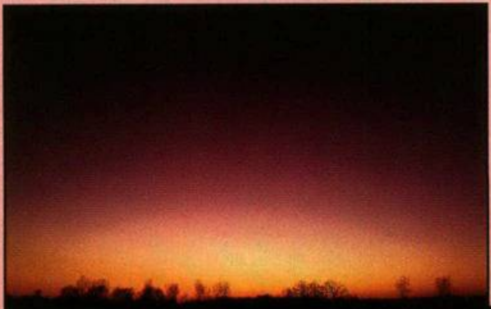
A few minutes after sunset, the sky lacks its normal rainbow coloration. Close to the horizon the sky looks amber or gold. This fades into a zone of white that blends into a pale magenta.

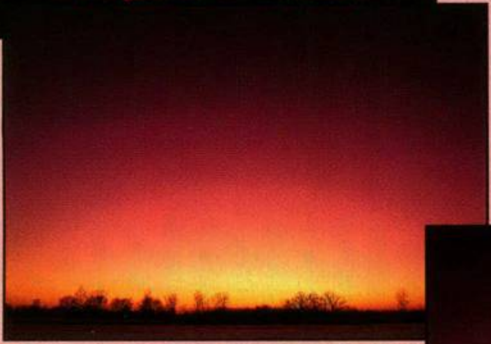
Ten minutes after sunset, the amber deepens in intensity while above it the sky color begins to turn a striking purple.

Twenty minutes after sunset, the purple twilight is at its peak.

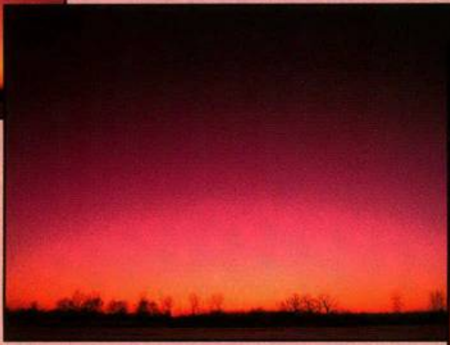
Forty to fifty minutes after sunset, the purple has faded to black. The stars are appearing above a band of vivid orange or deep red above the western horizon.

5 minutes after sunset



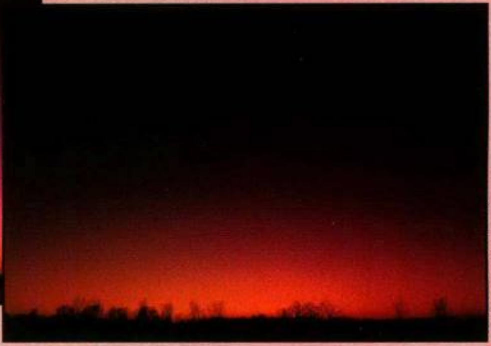


10 minutes after sunset

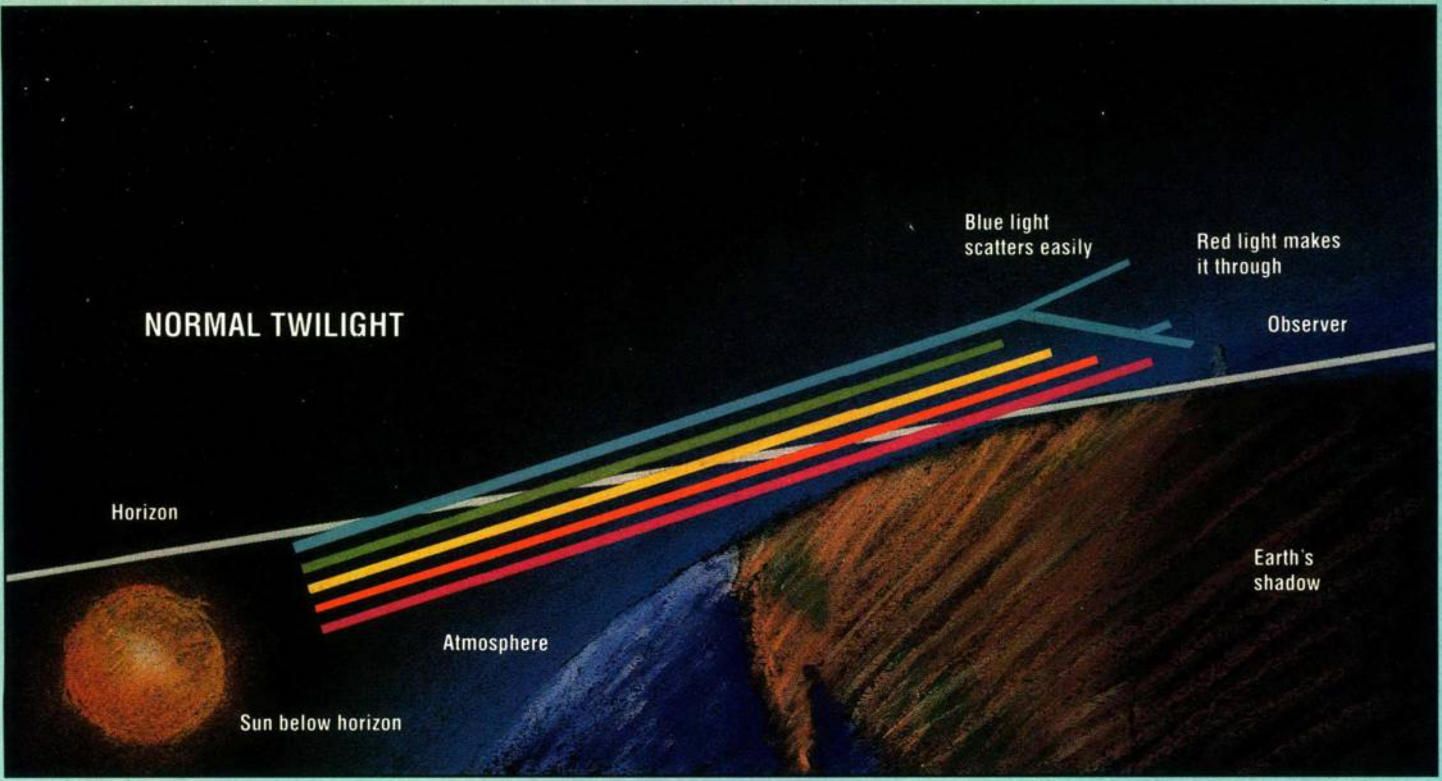


20 minutes after sunset

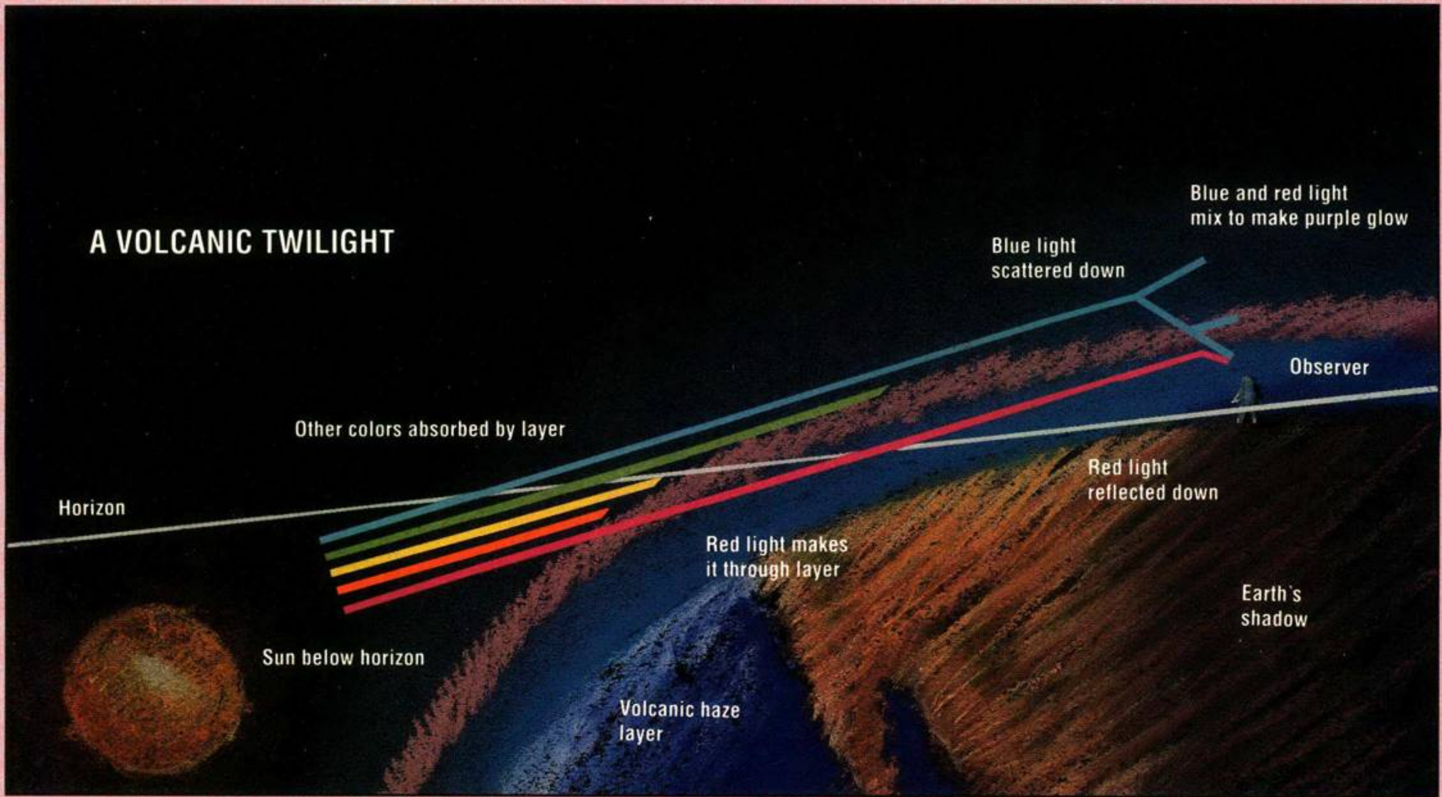
40 minutes after sunset



ASTRONOMY: Alan Dyer


NORMAL TWILIGHT
Blue light scatters easily
Red light makes it through
Observer
Horizon
Earth's shadow
Atmosphere
Sun below horizon

IN A CLOUDLESS SKY and with no volcanic haze layer present, all the colors of the spectrum penetrate through the atmosphere, with short-wavelength colors (violet and blue) scattering first. This creates a western sky painted with the full range of colors. In the eastern sky, the rising shadow of Earth creates a dark blue band along the eastern horizon.


A VOLCANIC TWILIGHT
Blue and red light mix to make purple glow
Blue light scattered down
Observer
Other colors absorbed by layer
Red light reflected down
Horizon
Red light makes it through layer
Earth's shadow
Sun below horizon
Volcanic haze layer

ASTRONOMY: Illustrations by Phil Kirchmeier

DURING VOLCANIC SUNSETS, the added haze layer blocks most of the colors. However, red light makes it through, lighting up the haze layer. This red light mixes with scattered blue light from higher up to create a beautiful purple glow for a few minutes after sunset.

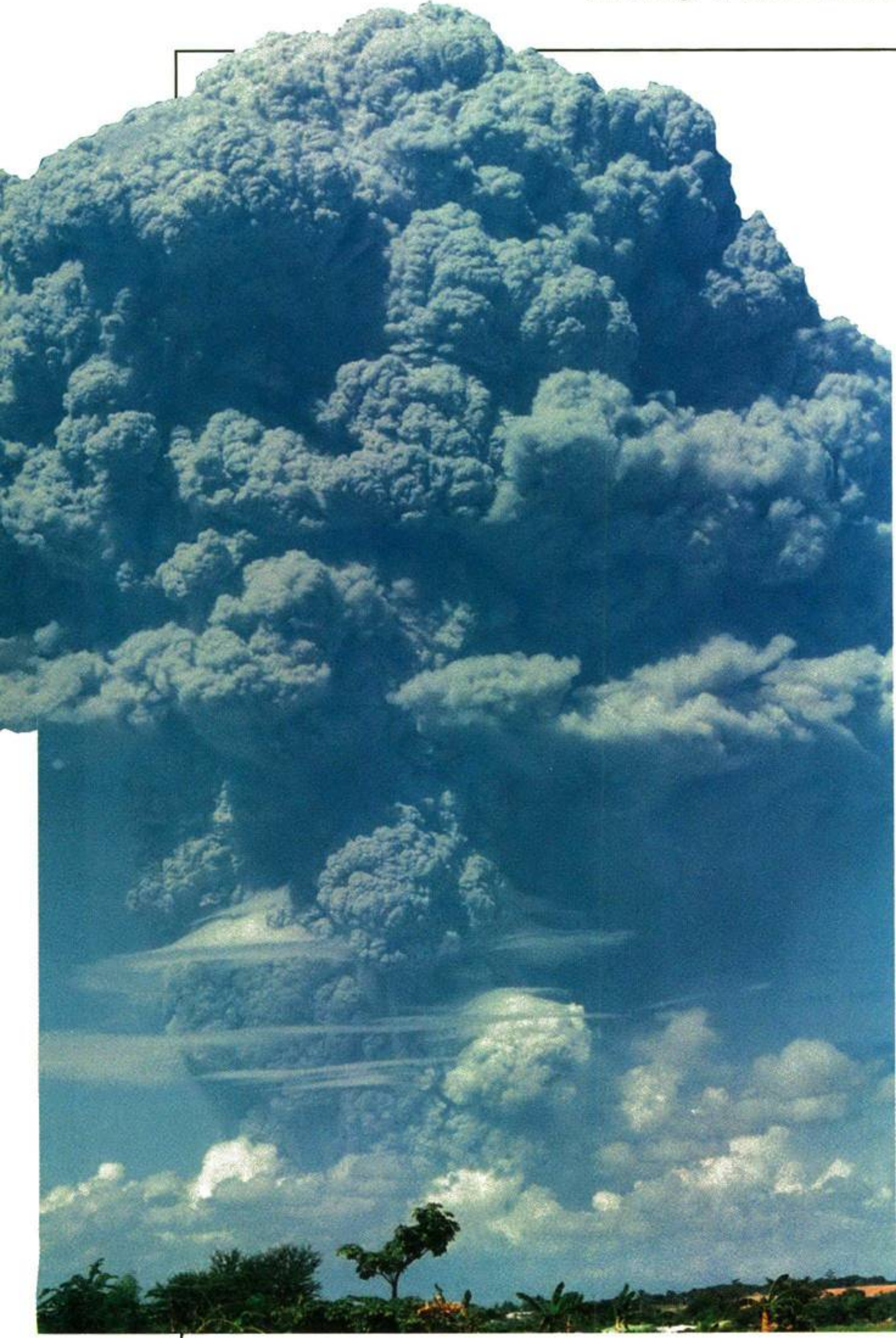
At this point, depending on your location, one of two things can happen: Most often the colors simply fade gradually into the coming darkness. But if you are fortunate, after the purple and gold disappear, the sky along the horizon is left a startling shade of angry red that can linger up to 60 minutes after sunset. On these occasions, the blood-red sky impresses everyone who sees it.

The Color Purple

The parade of colors during a volcanic sunset is a combination of the light that scatters off the volcanic aerosols and the filtering that takes place between the high-altitude aerosol layer and our eyes.

Air molecules by themselves scatter mostly blue and violet light. But volcanic aerosols are larger than air molecules and scatter light of longer wavelengths. As a result, when the atmosphere is filled with aerosols, the entire range of colors becomes scattered about the sky. During the day, the sky within 30 degrees of the Sun appears almost white from the mixture of scattered colors.

In the evening about 15 to 20 minutes after sunset, as you gaze high in the western sky, only the upper atmosphere, the level well above the aerosol layer, is still in direct sunlight. This part of the atmosphere scatters deep-blue light to your eyes. At the same time, the aerosol layer at the 70,000-foot level is experiencing sunset and is lit by red sunlight. It scatters



Daniel V. Dungla

MOUNT PINATUBO'S ash and sulfur rose into the upper atmosphere where they formed a layer at approximately 70,000 feet. From there, they spread around the world, creating volcanic sunsets visible from all latitudes.

PINATUBO POINTS

- The eruption of Mt. Pinatubo, ranked as the biggest of this century, injected more than 20 million tons of sulfur dioxide into the atmosphere, double the amount for the previous major eruption, El Chichon, in 1982.
- Most material ended up at 70,000 feet, but the upper edge of the layer now extends up to 90,000 feet.
- The layer's sulfur dioxide particles are coagulating, growing in size, and gradually falling down into the upper troposphere which lies at 20,000 feet.
- The initial plume took 2 weeks to circle the globe, after which it diffused northward and southward.
- Most of Pinatubo's cloud traveled southward. Effects in the Northern Hemisphere were not as great as in the Southern Hemisphere.
- During late 1991 and early 1992, at temperate latitudes the density of the cloud went through several cycles of clearing and rebuilding as winds carried fresh supplies of material away from the equator.
- By April 1992, the cloud over the equator was clearing. The densest part of the cloud in the Northern Hemisphere was at 30° N latitude and in April had a total opacity as great as it had ever been since the eruption.
- After El Chichon's eruption, 14 months passed before the volcanic layer started to decay and 3 to 4 years before it had dissipated entirely. A similar schedule could apply to Pinatubo's haze layer.

the only color it can — red — because all the blue has been scattered away. The blue from the upper atmosphere and the red from the aerosol layer arrive together at your eyes. The result is a western sky that appears purple, a color that is a mixture of red and blue. This purple glow can extend across the western sky to an altitude of 20° to 30° above the horizon.

When you look below the twilight purple to the area of sky just above the horizon, you are seeing layers of air that are farther around the curve of Earth over an area where the Sun is still above the horizon. So 5° to 10° off the horizon, the aerosol layer there far to the west is nearing sunset and scatters yellow and orange light toward you.

However, the volcanic layer blocks green and blue light so a volcanic sunset lacks the full rainbow transition from deep blue through green, yellow, orange, to red. The hallmark of a volcanic sunset is a more limited palette — the purple glow above an orange horizon.

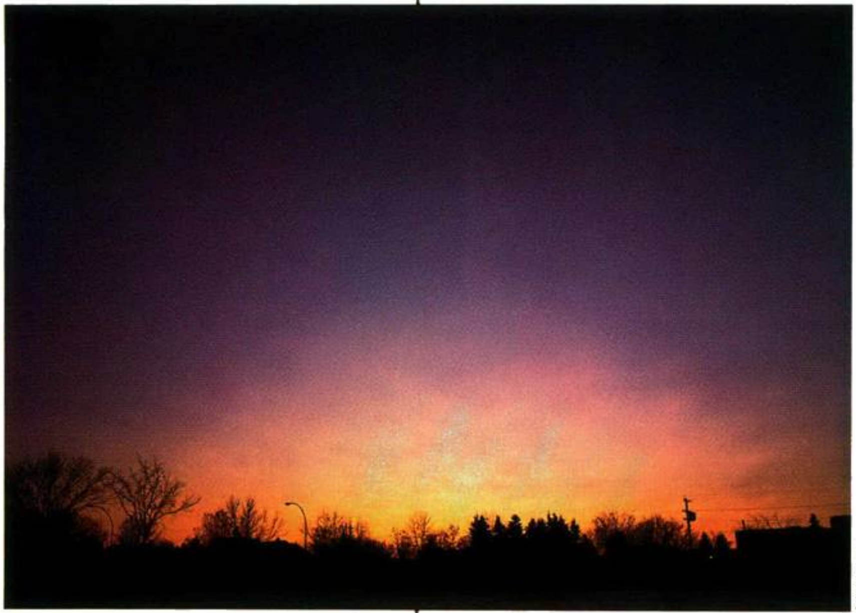
Seeing Red

Thirty to 40 minutes after sunset, the aerosol layer overhead and high in the west is now in darkness. Because there is no light to scatter toward you, most of the sky appears dark and the brightest stars are now visible.

But the aerosol layer above the horizon far to the west is still catching the last light of the setting Sun. Since the Sun's rays now have to make a long journey all the way through the lower atmosphere before they reach this layer, all the wavelengths of light except red get scattered out. The layer reflects the deep red light, rimming the western horizon with brilliant crimson.

This red usually fades to black, signaling the end of the show. With luck you might get a reprise — the red can reappear. If there are no clouds for a long distance past the horizon, your piece of volcanic layer can reflect the red twilight glow from its horizon. You're then seeing a reflection of a reflection.

PINATUBO'S ASH CLOUDS could be seen anywhere in the world and often appeared at sunset as wispy gray streaks in the western sky.



Alister Ling

This second twilight is quite rare. I've not had the good fortune of seeing the phenomenon myself from where I live, no doubt because in the mid-latitudes each weather disturbance blowing in from the west follows too closely on the heels of the previous one. It's tough enough to get clear skies overhead, let alone clear skies upstream too.

Waiting for the Dust to Settle

Can you expect to see bands of volcanic ash clouds every clear evening after sunset? Or purple and red sunsets every night? No. For one thing, you need a cloudless evening, and preferably cloudless conditions for a hundred or more miles to the west to give the setting Sun's light a clear path through the atmosphere.

However, even during clear weather, days can pass between good displays. Moving air masses in the upper atmosphere can concentrate the volcanic dust and droplets over some zones and thin it out over others, just as the lower atmosphere does with normal clouds. Although during a period of volcanic sunsets there is usually enough material to provide some degree of purple twilight, a vivid red afterglow is more rare.

How much longer the volcanic sunsets will continue is difficult to say. After previous massive eruptions, such as that of Krakatoa in 1883, there were occasional relapses of volcanic sunsets for two to three years after the eruption. In addition, other eruptions can inject new clouds into the atmosphere at any time. (However, to produce volcanic sunsets, a volcano must explode with enough violence that its ash cloud pierces into the stratosphere.)

Earlier this year, Pinatubo sunsets seemed to be diminishing in intensity and frequency. The material was still present in the atmosphere but had diffused upward and downward enough that the twilight-enhancing layer was not as well defined. By 1993 Pinatubo's effects on the twilights may have disappeared entirely. In the meantime, keep watching the sky every clear evening (or morning for that matter). With luck you'll be rewarded with a show of colors staged by a volcano half a world away. □

Alister Ling is a meteorologist with Environment Canada and is an avid deep-sky observer awaiting the return of pre-Pinatubo clear skies.

COBE'S BIG BANG!

Observations of the early universe made by the Cosmic Background Explorer satellite reveal the seeds that grew into the galaxies and galaxy clusters we see today.

by Richard Talcott

Structure pervades the universe. Everywhere astronomers look, they see it. Anyone who goes outside on a clear night and gazes at the sky can see the most obvious structure. The planets and stars — distinct points of light surrounded by the blackness of space — confirm that matter clumps together more in some regions than in others.

As astronomers probed deeper into space this century, they found new levels of structure. Stars clumped into galaxies, and galaxies clumped into clusters. Within just the last two decades, astronomers have discovered that the clusters of galaxies themselves clustered into superclusters, which are separated by huge and apparently empty voids.

Structure seemed to be everywhere, except at the largest and most distant scale of all. When astronomers observed the cosmic microwave background — the remnant radiation from the big bang that gave birth to the universe — it appeared extraordinarily smooth. There was no hint of any structure at all. Everyone agreed that there had to be some irregularities in the otherwise featureless background, some seeds around which gravity could pull in matter to form the galaxies, but no one could find them. Until now.

In late April, a team of astronomers led by George Smoot of the Lawrence Berkeley Laboratory and the University of California announced that the Cosmic Background Explorer satellite (COBE for short) had discovered tiny variations in the temperature of the microwave background. According to Smoot, "These small variations are the imprints of tiny ripples in the fabric of space-time put there by the primeval explosion. Over billions of years, the smaller of these ripples have grown into galaxies, clusters of galaxies, and the great voids in space."

An Historic Finding

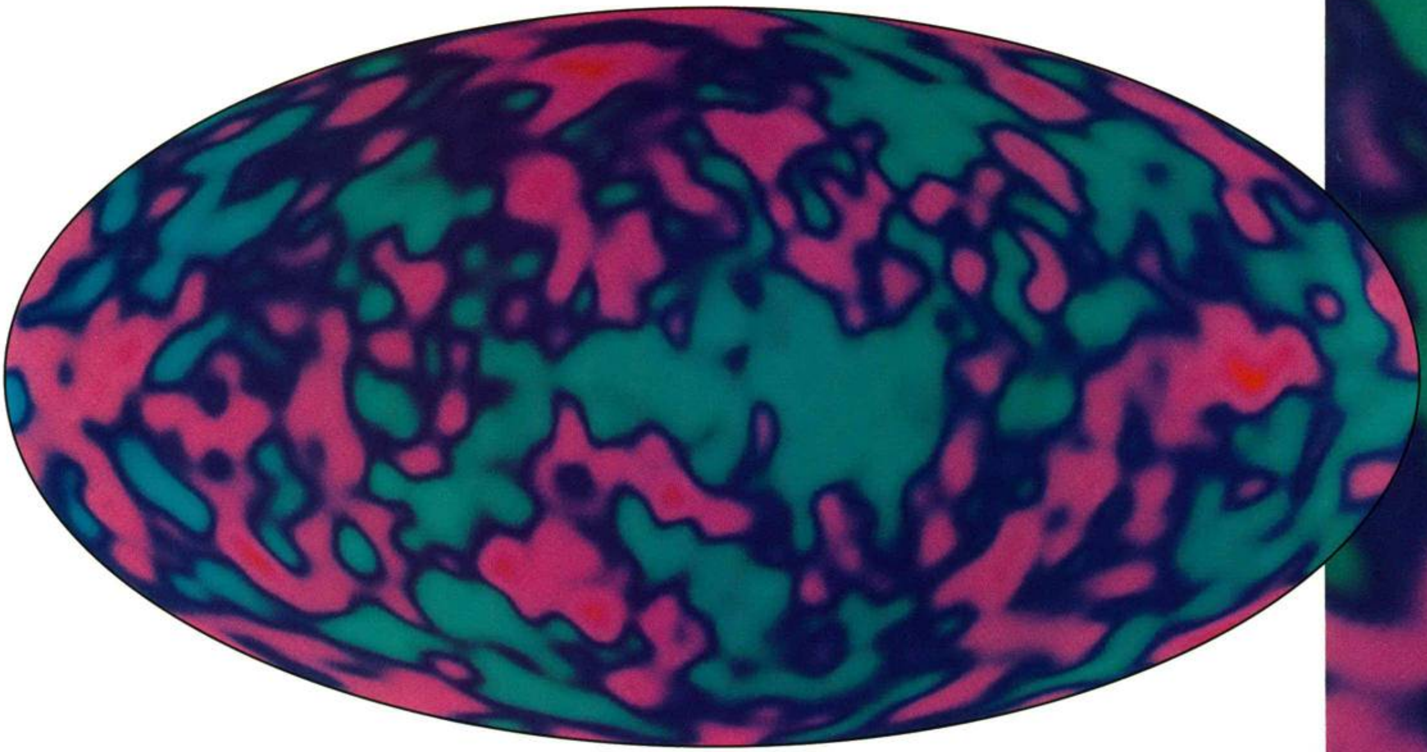
Speaking for many astronomers, University of Pennsylvania cosmologist Paul Steinhardt stated that if this finding is confirmed, it would rank as "not only one of the most important discoveries in cosmology, but one of the most important discoveries in science in this century." Yet this momentous discovery is based on just the tiniest variations.

The ripples are actually minuscule differences in the temperature of the background radiation. Embedded in the background radiation, which has a temperature of 2.73 kelvins (2.73° Celsius above absolute zero), the ripples represent deviations of just 30 millionths of a degree. That's equal to 1 part in 100,000 of the total signal.

The ripples appeared in observations made with COBE's Differential Microwave Radiometers. The six radiometers have been observing the sky continually since COBE's launch in November 1989. The discovery comes from data collected during the first year of the satellite's life. In that time, each of the six radiometers collected roughly 70 million measurements, for a total of nearly half a billion measurements. Then the computers went to work. Alan Kogut, a team member at Goddard Space Flight Center, says "Each of those measurements is like one piece of a gigantic jigsaw puzzle — you look at the piece by itself and it could mean anything. It's only when you fit all 70 million pieces for each of the radiometers together that the pattern starts to emerge."

The astronomers analyzed these measurements statistically to get the results. Although the statistical nature of the analysis means you can't point to any specific area of the sky and say, "Yes, this spot is one part in a hundred thousand hotter than that spot over there," it is a tried-and-true method for getting more sensitivity out of an instrument.

Team members didn't announce results immediately, however. They kept it to themselves for a year or more so the data and the computer programs



NASA/Goddard Space Flight Center

SEEDS OF STRUCTURE permeate the microwave background (red indicates variations 0.01% warmer and blue 0.01% cooler than the average 2.73 kelvins). Instrument noise causes most of the patchiness shown, but statistical analysis also indicates the presence of tiny — 0.001% — cosmic signals.

could be checked, re-checked, and checked again. They wanted to be sure they were seeing a cosmic signal and not a spurious one. And now, they are as sure as they can be.

What It Means

The discovery is far more than a single piece of the cosmological puzzle. It provides direct support for the theory of inflation, which proposes that the universe expanded extraordinarily fast for a brief period just after the big bang. It also supports the cold dark matter model of how the universe's observed structure arose. And even more importantly, it eliminates a large number of competing models.

The big bang theory grew out of Edwin Hubble's discovery in the 1920s that the galaxies are flying apart from one another and that the farther away a galaxy is, the faster it moves. But if the universe were expanding as this suggested, then at some point in the distant past, all the galaxies would have been much closer together. The big bang theory states that the entire universe was once packed into a point of infinite density and extraordinarily high temperature. The big bang created not only the universe and all the matter in it, but also the space that makes up the universe and time itself.

As the universe expanded, it cooled. But for a long time, the temperature was too hot for atomic nuclei to capture electrons. Photons of light could travel only short distances before interacting with free electrons. Then, when the universe's temperature fell below 5,000 kelvins roughly 300,000 years after the big bang, atoms formed. With electrons tied up in atoms, radiation could travel freely, and the universe became transparent to light.

This is the light astronomers see when they look at the microwave background radiation. But the radiation no longer has a temperature of 5,000 kelvins. Instead, the expansion of the universe has cooled the radiation to just 2.73 kelvins.

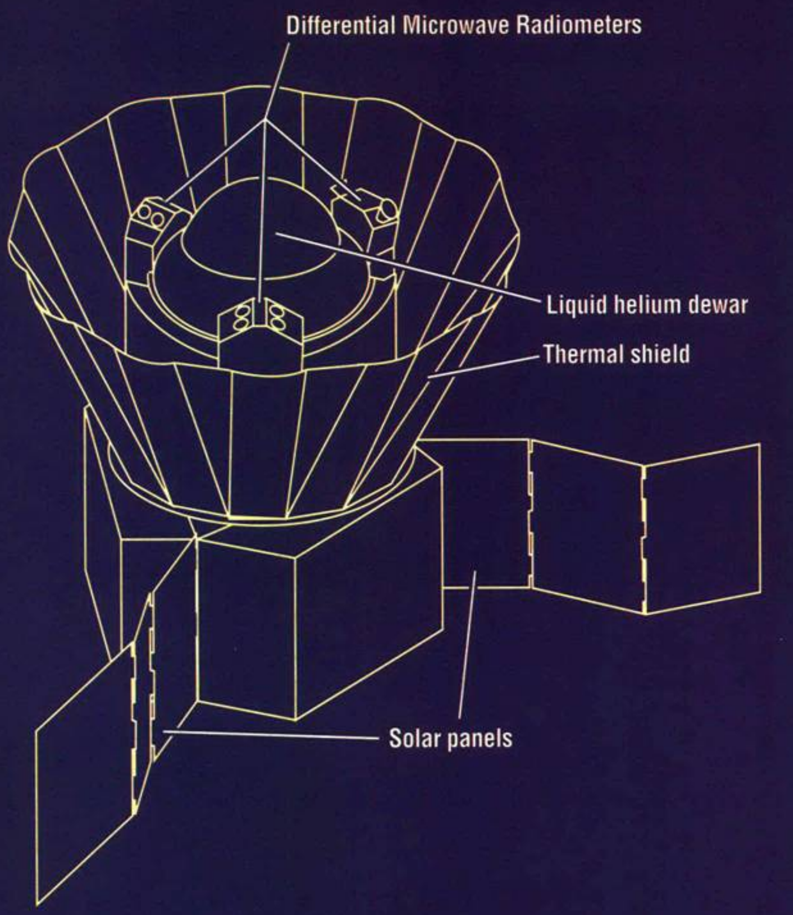
Beautiful, but Incomplete

For such a simple theory, the big bang theory works amazingly well. It explains the expansion of the universe. It predicts the correct abundances of hydrogen and helium, the two most common elements in the universe, which formed in the first few minutes after the big bang. But perhaps most impressively, it predicts the microwave background radiation. When Bell Labs researchers Arno Penzias and Robert Wilson detected this remnant radiation in 1964, astronomers quickly hailed the big bang as the best game in town.

Despite its power, the big bang was too simple to be a complete theory. It offered no reasons for many of the observed properties of the universe. For example, as astronomers examined the microwave background radiation, they found it to be incredibly isotropic — it appeared to have the same temperature no matter what direction they looked. But the big bang theory couldn't produce this. There was no way material in one part of the universe could communicate with material in a distant part of the universe so that they could reach equilibrium.

Inflationary models easily explain how matter and radiation reached equilibrium. First developed by MIT physicist Alan Guth in 1980, the inflation theory proposes that shortly after the big bang (10^{-35} second, or 10 trillion trillion trillionths of a second, to be exact), the universe underwent an exponential expansion that increased its size enormously (by a factor of 10^{50}). Before that time, the universe was small enough that widely separated parts could reach equilibrium, and that equilibrium persisted after the inflationary epoch ended.

What motivated inflation, according to Steinhardt, was an *a posteriori* prediction, or "postdiction." In other words, we had observations that



PROBE OF THE BIG BANG, the Cosmic Background Explorer detected ripples in space-time. Inside the thermal shield and surrounding the liquid helium dewar are COBE's Differential Microwave Radiometers, which discovered the ripples.

NASA

couldn't be explained under existing theory, so we developed a new theory that could explain them. Though inflation made predictions, no experimental confirmation existed.

As Steinhardt recalls, "A number of cosmologists got together to see whether any fluctuations might be left after inflation. And we discovered the surprising prediction that inflation leaves behind some inhomogeneities, or ripples, in the universe, and these ripples have a characteristic spectrum.

"The important thing about the COBE results is that the ripples agree with this spectrum, at least within the first limits that the researchers found. That's the first prediction, rather than a postdiction, made by inflation to be confirmed."

Wanted: Matter, Cold and Dark

COBE's results also support the contention that lots of "dark matter" exists in the universe. In fact, as much as 90 percent or more of the universe may be in the form of dark matter, which is unlike ordinary matter and can be seen only through its gravitational effect on ordinary matter. (See "Shedding Light on Dark Matter," February 1992.)

Smoot says the temperature and size of the variations discovered by COBE agree with theories of dark matter. "Theory tells us that these vast regions cannot be composed of ordinary matter. It must be something we've never seen in our laboratories. If it were ordinary matter, which interacts with light, then we would see much greater temperature variation. Only matter that does not interact with light except through gravity could cause such slight temperature variation."

Dark matter can take many forms, but the COBE results seem to point toward cold dark matter as the best candidate. Cold dark matter consists of slow-moving, massive particles that can gravitationally bind together fairly easily to form the seeds that subsequently draw in ordinary matter. Other possible seeds bandied about by theorists include hot dark matter (faster moving cousins of cold dark matter) and various defects in the topology of space called textures, cosmic strings, and domain walls.

Paul Steinhardt explains the significance of COBE's findings: "What COBE has done has, first of all, produced results that are consistent with the basic outlines of inflation and are consistent with the cold dark matter picture. And, as it now stands, COBE has wiped out the texture scenario entirely. It's also wiped out the domain wall scenario. And finally, it's wiped out all of the cosmic string scenarios except for those where you have strings plus hot dark matter."

What the Future Holds

The COBE results are impressive, but everyone involved cautions that they need to be confirmed. That confirmation may come sooner rather than later. Balloon-borne experiments and telescopes at the south pole are looking for these same variations and achieve nearly the same level of sensitivity as COBE. In addition, there's another year's worth of COBE data for Smoot's team to analyze.

The confirmation may come within the next year or so. Steinhardt thinks that within a year we'll either see that something has fooled COBE or have confirmation. If it is confirmed, Smoot says, "Our results will unify physics on the largest and smallest scales, fusing together the fields of particle physics and cosmology." When that day comes, we'll all know a lot more about how our universe got to be the way it is. ☐

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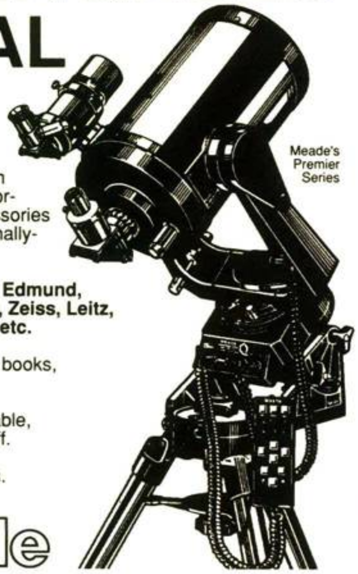

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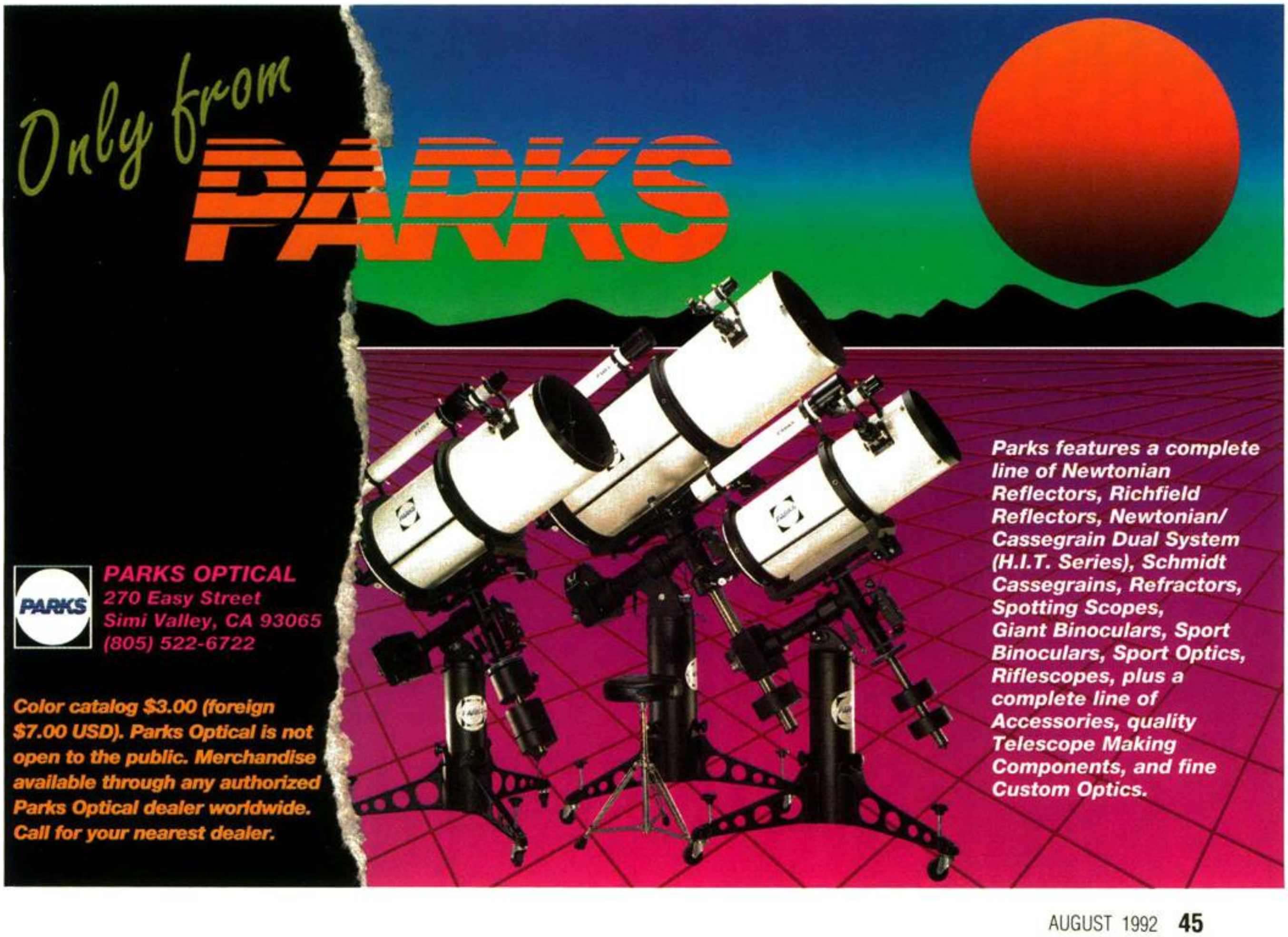

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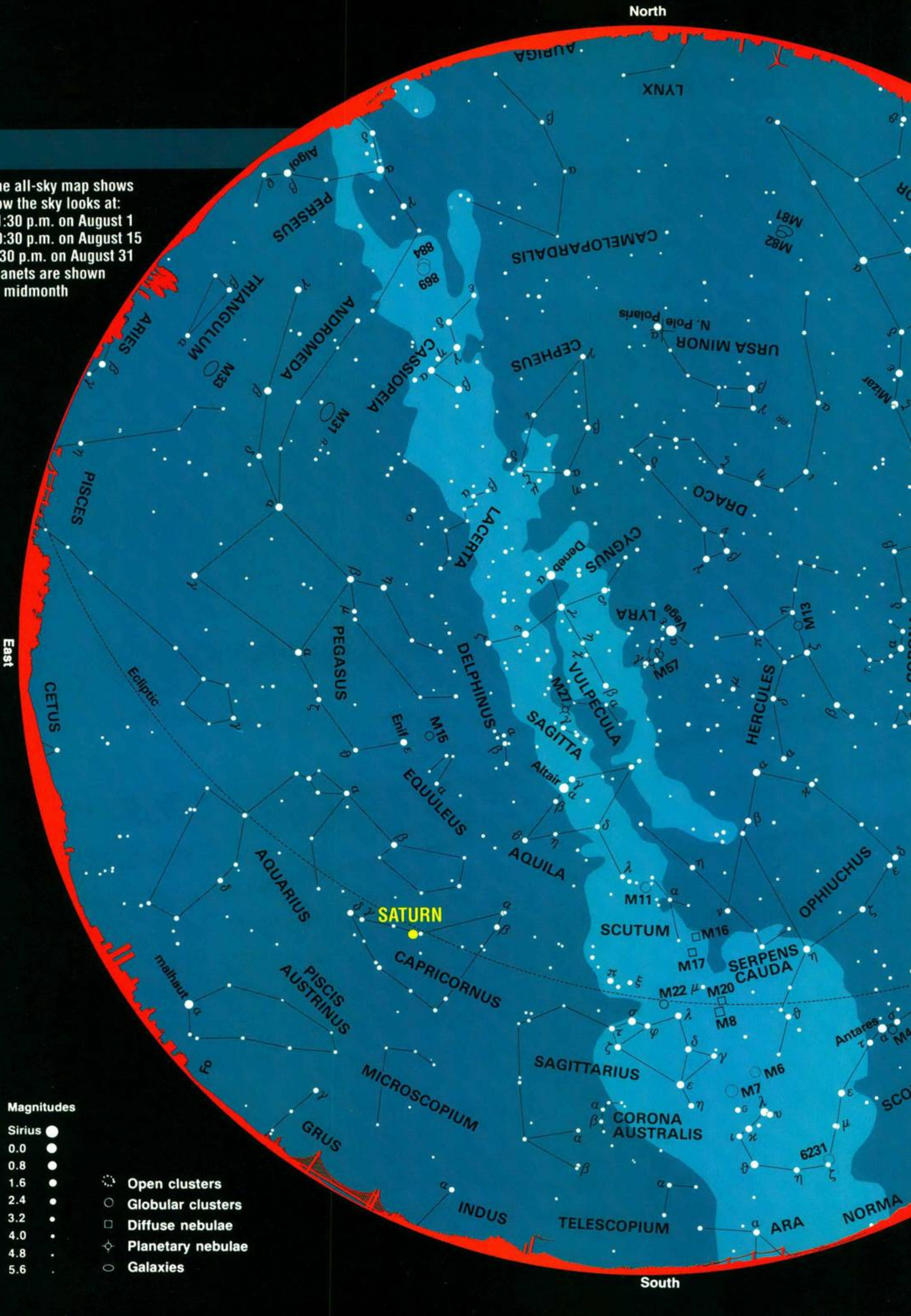
The all-sky map shows
how the sky looks at:
11:30 p.m. on August 1
10:30 p.m. on August 15
9:30 p.m. on August 31
Planets are shown
at midmonth


North
South
East
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LYNX
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CASSIOPEIA
CEPHEUS
N. Pole Polaris
URSA MINOR
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M31
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DRACO
CYGNUS
Deneb
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M57
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Ecliptic
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Enif
M15
EQUULEUS
Altair
AQUILA
OPHIUCHUS
AQUARIUS
SATURN
M11
SCUTUM
M16
M17
SERPENS CAUDA
CAPRICORNUS
PISCIS AUSTRINUS
Fomalhaut
M22
M20
M8
Antares
SAGITTARIUS
M6
M7
MICROSCOPIUM
CORONA AUSTRALIS
GRUS
6231
INDUS
TELESCOPIUM
ARA
NORMA
Magnitudes
Sirius
0.0
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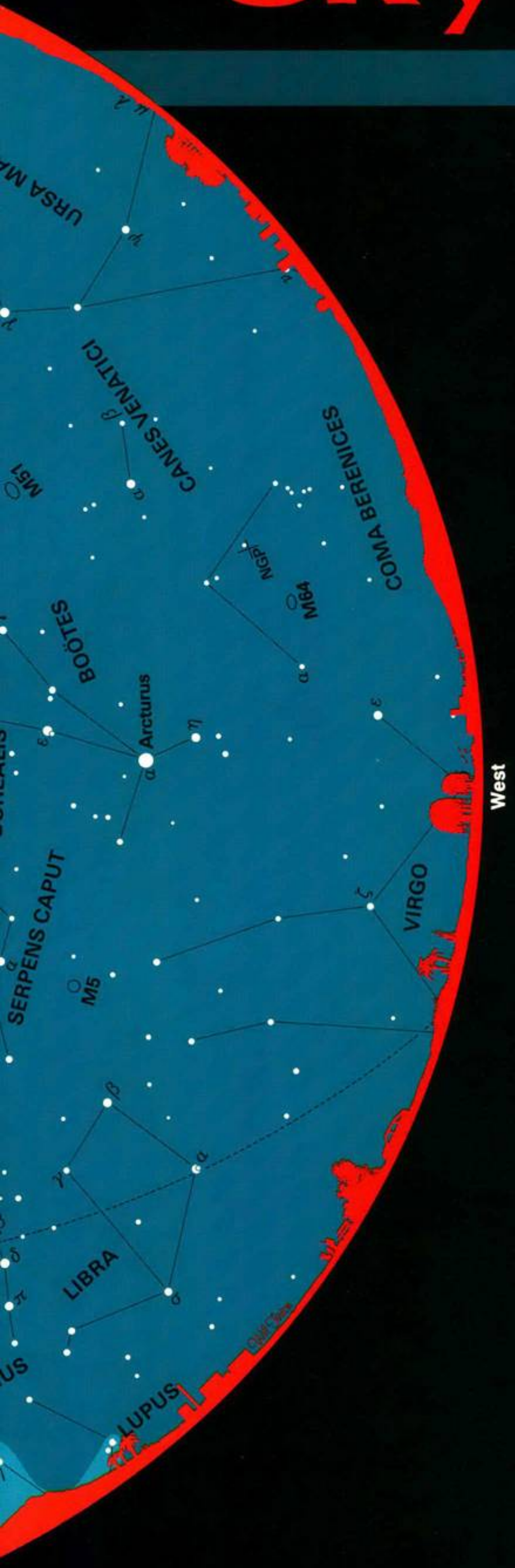
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

August 1992



SATURN AT ITS BEST

This is the month to look for Saturn because it is at its brightest for the year and visible all night long. At opposition on August 7, the ringed planet shines at magnitude 0.2 and rises at sunset, reaches its highest elevation in the south around midnight, and sets at sunrise. Saturn also appears largest in a telescope this month, with a globe that measures 19" across and rings that span 42".

A DAZZLING PLANETARY DUO

Keep your eyes on the evening sky this month, because the two brightest planets pass by one another. As the month progresses, Venus rises out of the western twilight glow while Jupiter sinks into it. On the evening of August 22, the two planets pass within 0.3° of each other and to the naked eye appear almost to merge.

MERCURY BRIGHT BEFORE DAWN

The innermost planet puts in one of its best appearances of 1992 in the August morning sky. Look for the 0.0-magnitude object around its greatest elongation on August 21, when the planet lies 11° above the eastern horizon 30 minutes before sunrise.

Calendar of Events

2	Mercury is in inferior conjunction
5	First Quarter Moon is at 6:58 a.m. EDT
6	Venus passes 1.1° north of Regulus, 2 p.m. EDT
7	Saturn is at opposition
11	Mars passes 5° north of Aldebaran, 5 a.m. EDT
12	Perseid meteor shower peaks The Moon passes 5° north of Saturn, 9 p.m. EDT
13	Full Moon is at 6:27 a.m. EDT The Moon is at apogee (252,508 miles from Earth), 11:38 a.m. EDT
20	Mercury is at greatest western elongation (18°)
21	Last Quarter Moon is at 6:01 a.m. EDT
22	The Moon passes 1.4° north of Mars, 5 p.m. EDT Venus passes 0.3° north of Jupiter, 11 p.m. EDT
26	The Moon passes 5° south of Mercury, 9 p.m. EDT
27	The Moon is at perigee (222,060 miles from Earth), 1:39 p.m. EDT New Moon is at 10:42 p.m. EDT
29	The Moon passes 7° south of Venus, 3 p.m. EDT

Eye on the Sky

by Deborah Byrd

SATURN IN THE SUMMER

The best-known ringed planet, Saturn, comes to opposition on August 7. That's when Earth passes between Saturn and the Sun, causing the planet to appear opposite the Sun in our sky. On the night of opposition, Saturn rises at sunset and swings slowly across the sky until dawn.

Though you need a telescope to see Saturn's rings, the planet itself is easy to recognize as a steady point of golden light in the constellation Capricornus. Saturn is now at its closest to us for the year, about 825 million miles away. As a result, it also appears at its brightest for the year, magnitude 0.2. Saturn takes nearly 30 years to complete one orbit around the Sun. It reached aphelion, or farthest point from the Sun, in 1988. Now it's drawing closer to the Sun; its perihelion, or closest point, will come in 2003. Thus the planet is several million miles closer to us this year than it was at last year's opposition. Still, Saturn isn't quite as bright at this opposition as it was last year because its rings now appear less open as seen from our earthly vantage point. Thus the rings reflect less total sunlight in our direction and Saturn looks fainter.

Be sure to look for Saturn and the Moon on the night of August 12/13. The Moon is Full on the morning of the 13th. It's no coincidence that a planet appears near the Full Moon around the time of its opposition. On the day that it becomes Full, the Moon is opposite the Sun. Saturn is also opposite the Sun now, and thus we see both of these worlds in the same direction in space.

WILL THE PERSEIDS ROAR THIS YEAR?

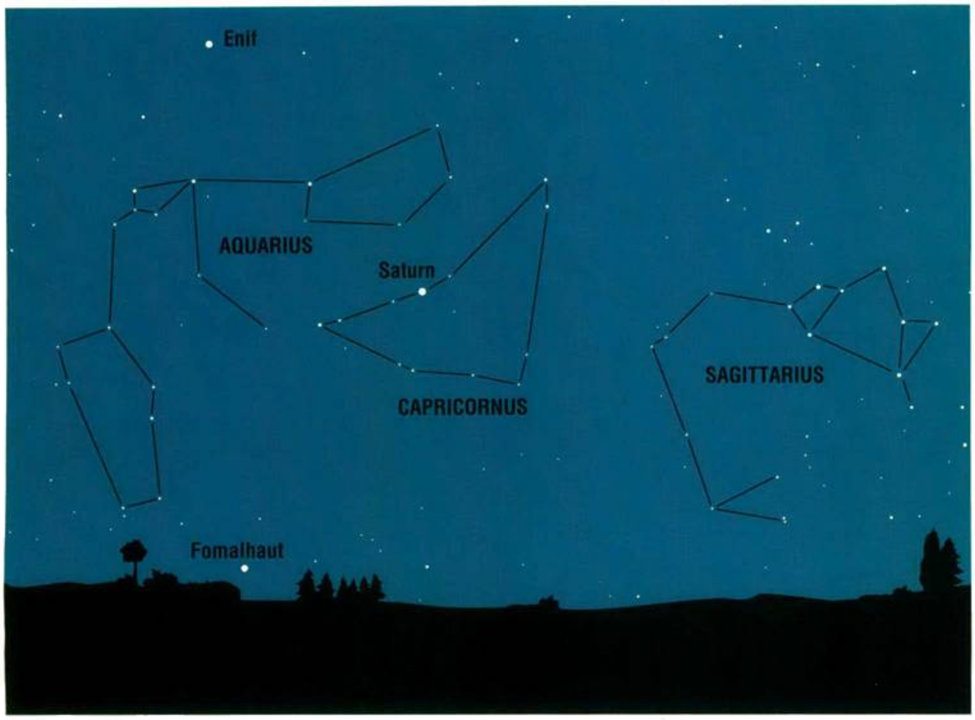
This year's Perseid meteor shower peaks on the night of August 11/12. Unfortunately, the Full Moon arrives just a day later and interferes with meteor observing. But don't give up on the Perseids altogether — there's a chance that this year's shower could produce a rare and spectacular storm.

The streaks of light that we call meteors, or "shooting stars," actually stem from debris left behind in the orbits of comets. The parent comet of the Perseids is Comet Swift-Tuttle, which was last observed in 1862. Because this comet's orbit around the Sun was thought to be 120 years long, people have been expecting it to return since the early 1980s, but no one has spotted it yet. Astronomers now suspect the true orbital period of Swift-Tuttle might be closer to 130 years and that the comet may reach perihelion this year.

Great meteor storms sometimes accompany the return of a parent comet. Unusual activity accompanied last year's Perseid meteor shower. Observers in Japan reported a rate of 350 meteors per hour for a brief time around the shower's peak. Elsewhere on Earth, the observed rates were lower but still plenty respectable at about 100 meteors per hour. The 1991 Perseid burst seems to have lasted only an hour or two, but it's possible that this short, strong surge of meteors might have stemmed from a mass of particles moving ahead of the returning comet.

Naturally, astronomers have calculated when we will be passing again through the same part of the Perseid meteor stream that

SATURN SHINES BRIGHTLY in the southeast after darkness falls this month. The ringed planet reaches opposition on August 7, when it is at its brightest and visible all night long.



produced last year's outburst. The answer is about 22h UT (shortly before nightfall for us in North America) on the evening of August 11. The annual peak of the shower is scheduled for shortly after midnight that night. And don't forget that most meteor showers are best observed before dawn, when the part of Earth you're riding on has turned head-on into the meteor stream. A camp-out for the night of August 11/12 may be in order!

A PAIR OF EVENING PLANETS

Late last month, the sky's brightest planet, Venus, emerged from the twilight glare. This month, Venus slowly climbs higher into the western evening sky. Meanwhile, the second-brightest planet, Jupiter, is sinking lower every evening in this same part of the sky. These two worlds make a spectacular sight when they pass just 0.3° from each other on the evening of August 22. Start looking for the two planets low in the west no later than half an hour after the Sun goes down. They make a pretty pair, but only because both shine so brilliantly.

AUGUST'S PLANETS

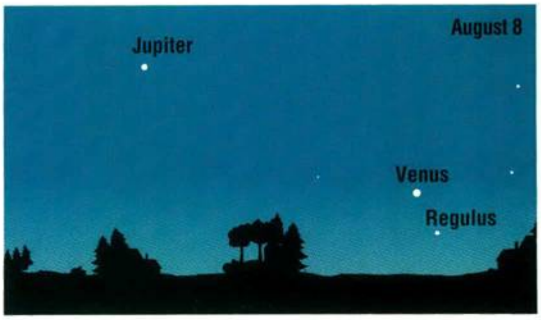
Planets are visible throughout the night this August. The first one to pop into view after the Sun goes down is **Venus**. It lies low in the west after sunset. Each time night comes again, the planet lies minutely higher in the western twilight sky. It will take a while to creep high enough to become really prominent, but you can see it now if you make the effort to look. Venus shines brilliantly this month at magnitude –3.9. Look for it above and to the right of the fragile crescent Moon on the evening of August 29. On that evening, binoculars might give you a last glimpse of Jupiter, below and to the right of Venus.

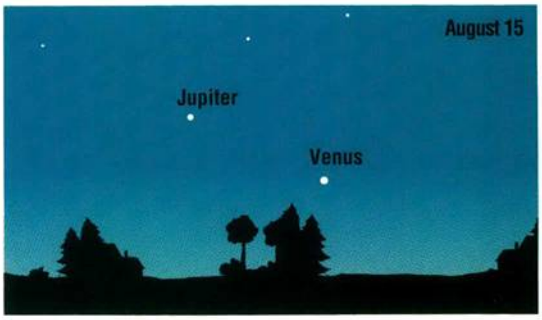
Jupiter, in the constellation Leo, begins the month higher in the western twilight sky than Venus. While Venus ascends, however, Jupiter drops into the Sun's glare. The two planets pass each other on the evening of August 22, when Jupiter is significantly fainter than Venus at magnitude –1.7. Two lesser lights seen so low in the sky wouldn't be visible. But you can enjoy seeing these two brilliant worlds against a background of bright evening twilight. The two are bright for different reasons. Venus shines brilliantly partly because it's near Earth and partly because its surface is covered with highly reflective clouds. Jupiter is cloud-covered, too, but its brightness stems more from its enormous size.

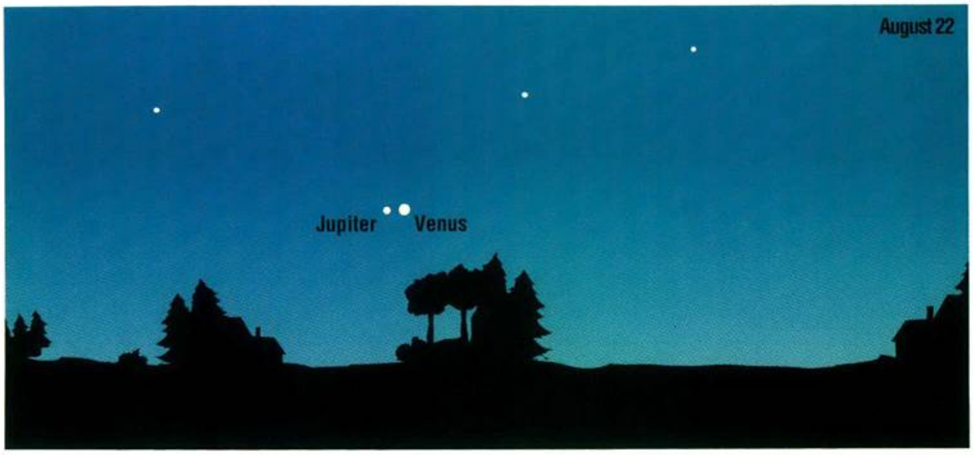
As August begins, you can find **Saturn** ascending in the southeast an hour after the Sun sets. On August 7, the planet reaches opposition when Earth passes between it and the Sun. As a result of its nearness to Earth, Saturn shines most brightly for the year at magnitude 0.2. It casts its gentle, golden light from among the background stars of the constellation Capricornus the Sea Goat, whose shape resembles an arrowhead.

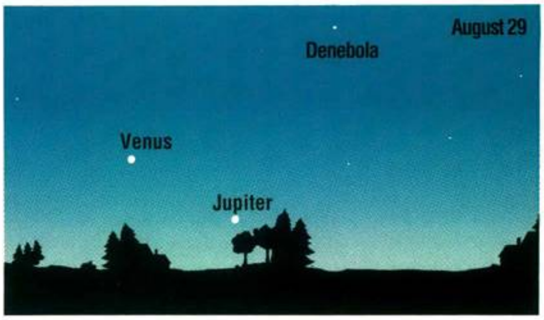
Mars rises just after midnight in August. It shines at magnitude 0.7, slightly brighter than last month because Earth is edging closer to it in our world's smaller orbit around the Sun. Mars is always fun to watch as it makes its beeline around our sky, but it's in a particularly good spot now in the constellation Taurus. This constellation contains two good asterisms, both of which are actual clusters of stars, the Pleiades and the Hyades. Mars begins the month in between these two.

On August 11, Mars passes 5° north of Aldebaran, the brightest star in

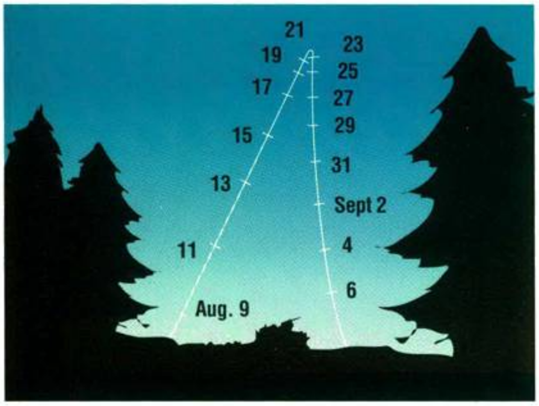








VENUS AND JUPITER GLIDE PAST one another in the evening sky this month. The two brightest planets are closest on the evening of August 22, when they appear just 0.3° apart in the west 30 minutes after sunset.



MERCURY CLIMBS HIGHER in the east each morning during mid-August, reaching a peak elevation of 11° one-half hour before the Sun rises on August 22.

Taurus, which is located in front of the Hyades. Since Aldebaran is a reddish star, and Mars is the Red Planet, you'll no doubt want to compare the colors and contrast the twinklings of these two lights in the sky.

Innermost **Mercury** was visible early last month in the evening twilight sky. On August 2, it swings between the Sun and Earth, emerging by mid-month into the morning twilight sky. Look for Mercury low in the east before sunrise beginning around mid-August. It shines brightly at magnitude 0.0 at greatest elongation on August 21. Then the planet is 18° west of the Sun in the predawn sky. Afterwards, it gets lower in the sky, but its brightness continues to increase, reaching magnitude –1.1 on August 31.

THE STARRY SKY

The Summer Triangle is a large asterism made of three bright stars — Deneb, Vega, and Altair — from the constellations Cygnus, Lyra, and Aquila, respectively. There are plenty of triangles among the stars, but you can always recognize the Summer Triangle because it has another large asterism inside it, also a fairly large pattern, in the shape of a cross. This is the Northern Cross in the constellation Cygnus the Swan.

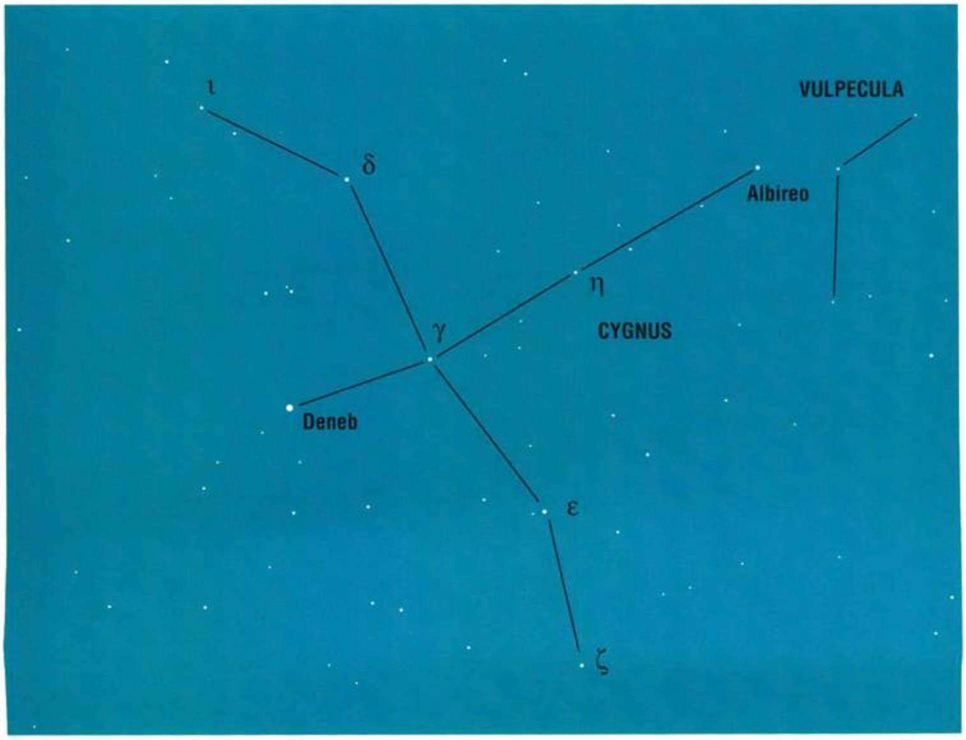
In a dark sky, you'll easily see that the Cross lies in the glittering band of the Milky Way. The Swan, which is the same asterism as the Cross, is equally easy to imagine; this figure has been seen as a great flying bird by a variety of cultures. Be sure to scan with your binoculars all around Cygnus on a moonless night. You'll be rewarded with myriad stars, star clusters, shimmering nebulae, and dark clouds of obscuring dust.

The bright star Deneb simultaneously marks the tail of Cygnus the Swan and the head of the Northern Cross. Deneb is a fascinating star, an extremely luminous supergiant that is the most distant of all the bright stars. Its apparent magnitude is 1.3, but it shines this brightly despite a distance of some 1,800 light-years. Near Deneb are the noticeable crossbar stars, with Gamma (γ) Cygni in the center and Delta and Epsilon (δ and ε) Cygni at opposite ends. The 3rd-magnitude star Albireo, at the head of the Swan, marks the foot of the Cross. It's a famous double star. Small telescopes show one component in the Albireo system as gold and the other as blue.

And there's more. Cygnus is jam-packed with fascinating objects and histories. For example, the star 61 Cygni — located at an estimated distance of only about 11 light-years — was the first star to have its distance measured. This feat was accomplished by Friedrich Bessel in 1838. At the time, it was called "the greatest and most glorious triumph that practical astronomy has ever witnessed."

Cygnus is also the site of history in the making. The two brightest ordinary novae in recent times have erupted within its boundaries. Many remember Nova Cygni 1975, which reached 2nd magnitude. Last winter Nova Cygni 1992 — the brightest nova since the one in 1975 — reached a peak magnitude of about 4.3 and remained visible to the naked eye for about 10 days. ☐

CYGNUS THE SWAN SOARS nearly overhead late on August evenings. This impressive constellation boasts fine Milky Way starfields as well as the 1st-magnitude star Deneb.



Deborah Byrd's new radio series, "Earth and Sky," can be heard on stations in the United States, Canada, and Guam.

by Rick Shaffer

SATURN RULES THE NIGHT

No object that backyard astronomers observe generates as much excitement as Saturn. Jupiter's chaotic atmosphere and Galilean satellites fascinate us and the Moon's great craters and mountains beckon for our attention. We spend hours seeking elusive deep-sky objects that challenge our observing skill. But we keep coming back to Saturn.

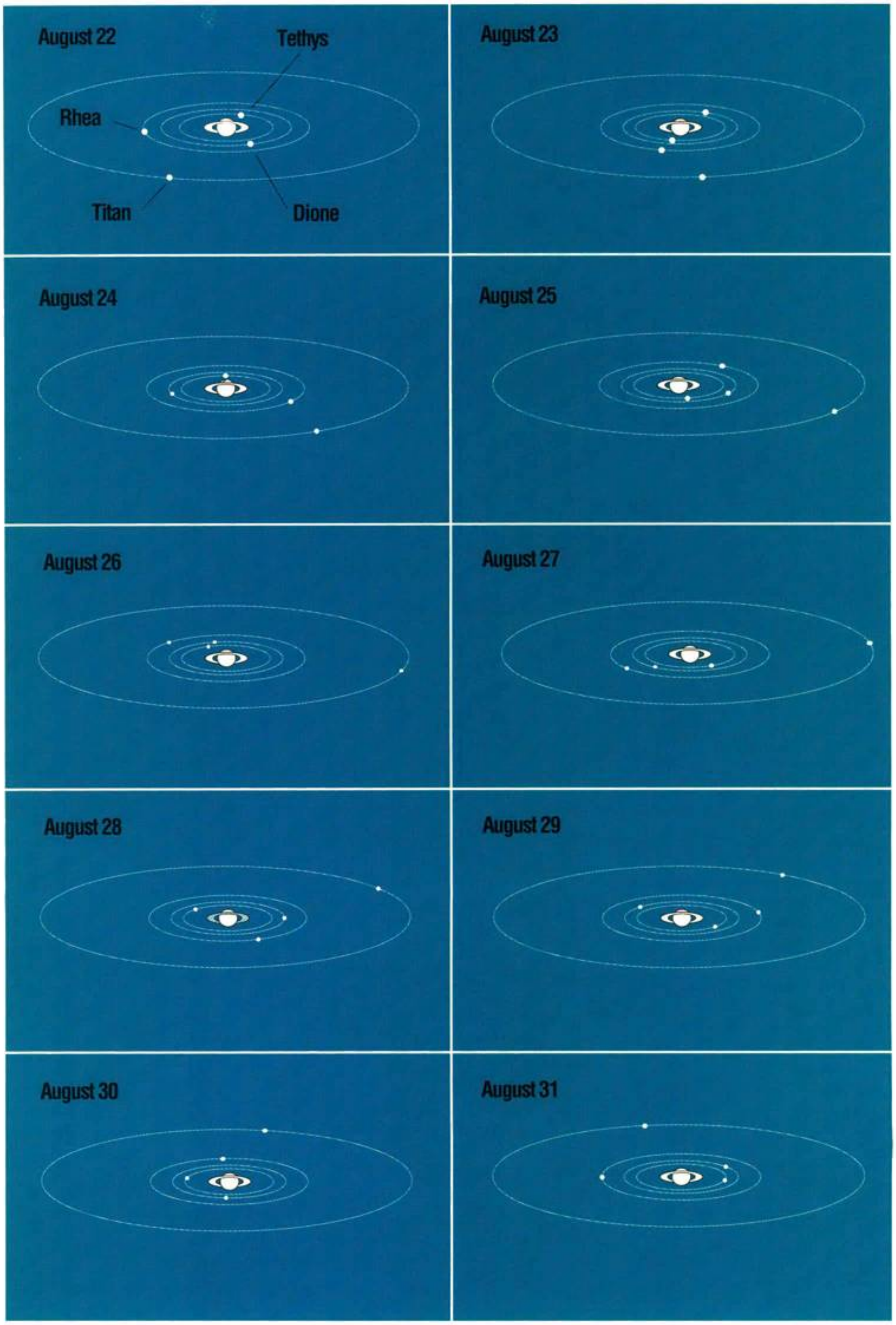
And so it will be this August. As crops grow to maturity and we bask in the full heat of summer, spend at least a few evenings gazing at Saturn and its glorious rings. You'll find the 0.2-magnitude planet among the background stars of Capricornus, though none of those stars comes close to outshining Saturn. With Saturn reaching opposition on August 7, all month long it rises near sunset, transits the meridian near midnight, and sets near sunrise.

The best time to observe Saturn this month is near midnight. That's when the planet reaches its highest point in the south, so you'll be viewing it through the least amount of Earth's atmosphere. Additionally, by midnight the atmosphere has had half the night to settle down, so the seeing is often steadier than in the early evening. However, don't rely solely on the time of night to provide good seeing. Also choose an observing site that minimizes atmospheric turbulence.

Picking a good site can mean something as simple as observing from the south side of your house to avoid hot air rising off the roof. And it can be as complex as scouting out a site at the north edge of a field or forest. Such sites don't build up a lot of heat during the day, so they don't spend all night releasing that heat into the atmosphere.

Saturn possesses atmospheric belts and zones similar to those on Jupiter, though Saturn's are much more subtle. You'll need to spend several minutes (I'd recommend 10 to 15) viewing the planet's globe to perceive the differences in brightness that differentiate each feature from its neighbors. You can also try a blue or green filter to heighten the contrast between the features on the globe of the planet.

Saturn's disk measures 19" across this month, less than half the apparent diameter of the rings, which span 42". Though the rings are not as wide open as they've been the past few years, we still see them from an angle about 16° above their plane. With the rings relatively large and open and Saturn relatively high in the sky, you should get some great views of the ringed planet in your telescope this month.



TURN YOUR SCOPE TO SATURN during the dark of the Moon and look for the planet's four brightest satellites. Positions are shown at midnight EDT (11 p.m. CDT, 10 p.m. MDT, and 9 p.m. PDT) with south at top and east at right.

But seeing Saturn needn't be all that you do. You can also try sketching the planet. First, carefully trace the disk of Saturn shown on page 59 using a black pen. (Make a photocopy enlargement if you want a larger scale.) Then make your drawing while seated comfortably at the eyepiece. Because Saturn is quite bright, you can use a dim white light to provide illumination.

The technique I find most useful for drawing Saturn is to shade the rings and globe uniformly with a #2 pencil and then carefully rub the shading with a piece of soft cloth. To draw light-colored details, merely erase the corresponding part of the disk or rings. To draw darker details, add many pencil lines and smudge them with your cloth.

TWO PLANETS IN ONE FIELD OF VIEW

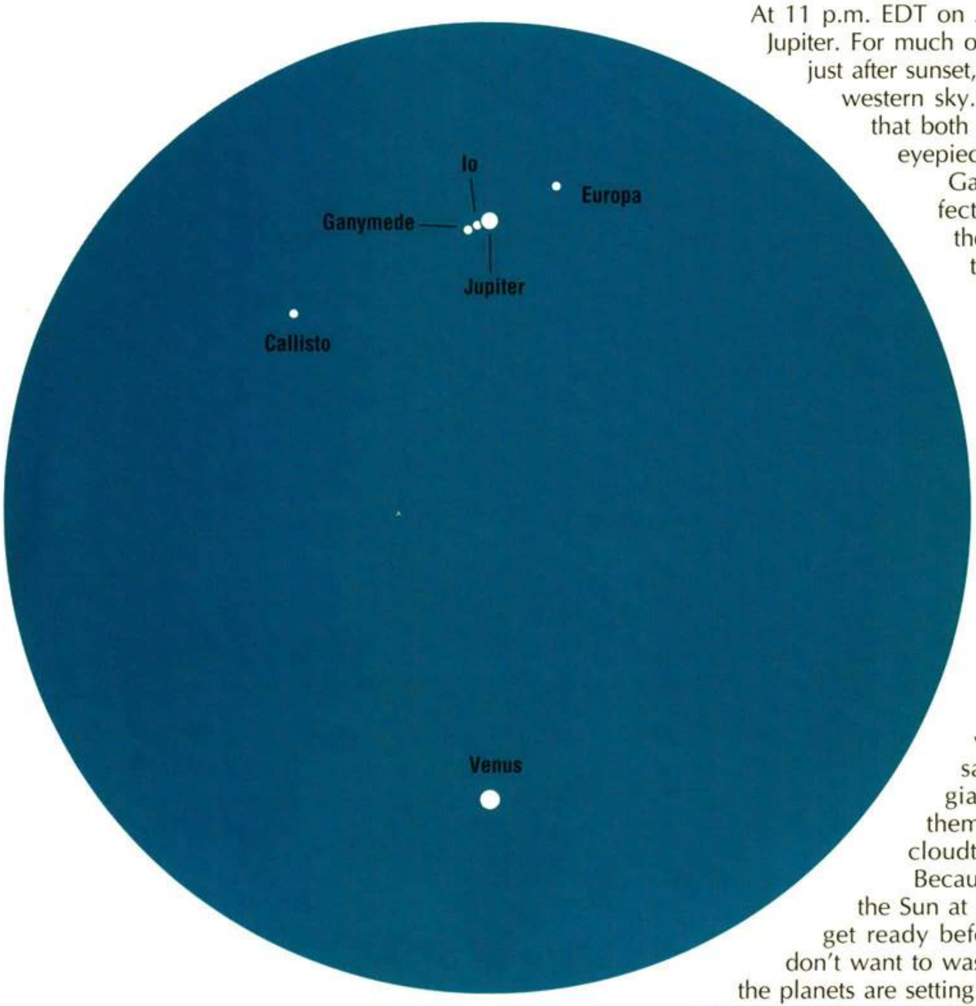
At 11 p.m. EDT on August 22, Venus passes 0.3° north of Jupiter. For much of the Americas, this conjunction occurs just after sunset, when Venus and Jupiter lie low in the western sky. The two planets appear close enough that both fit easily into the field of a wide angle eyepiece at 100x or more.

Gazing at the two planets together is a perfect opportunity to compare and contrast them. Jupiter appears three times larger in the eyepiece than Venus does (31" compared with 10"). However, Jupiter is actually almost 12 times the diameter of Venus. The smaller difference in angular size results from Jupiter's lying four times farther away than Venus.

The colors of the planets are caused by the way the planets' atmospheres reflect sunlight. Venus is enshrouded in almost perfectly homogeneous clouds that reflect the Sun's light with hardly any change in color. Thus, we see a pearly white disk. Jupiter, on the other hand, shows a disk of alternating dark belts and bright zones rich in shades of blue, brown, red, and white. With Venus and Jupiter in the same field of view, you can discern the giant planet's true colors by comparing them with the nearly pure white of Venus' cloudtops.

Because Venus and Jupiter lie only 19° from the Sun at the time of their conjunction, you must get ready before sunset to observe this event. You don't want to waste precious time trying to set up while the planets are setting. Also choose an observing site with an unobstructed view toward the western horizon.

If you expect the sky to be hazy, you might want to align your equatorial mount the night before. You can then use the setting circles to find Venus and Jupiter in the gathering darkness. Otherwise, slowly sweep the western horizon with binoculars or your finder to locate the planets.



VIEW VENUS AND JUPITER in the same field on the evening of August 22, when Venus passes just 0.3° north of Jupiter. This eyepiece view shows south at top and east at right to match the view in an inverting telescope.

A FAVORABLE VIEW OF AN ENORMOUS IMPACT

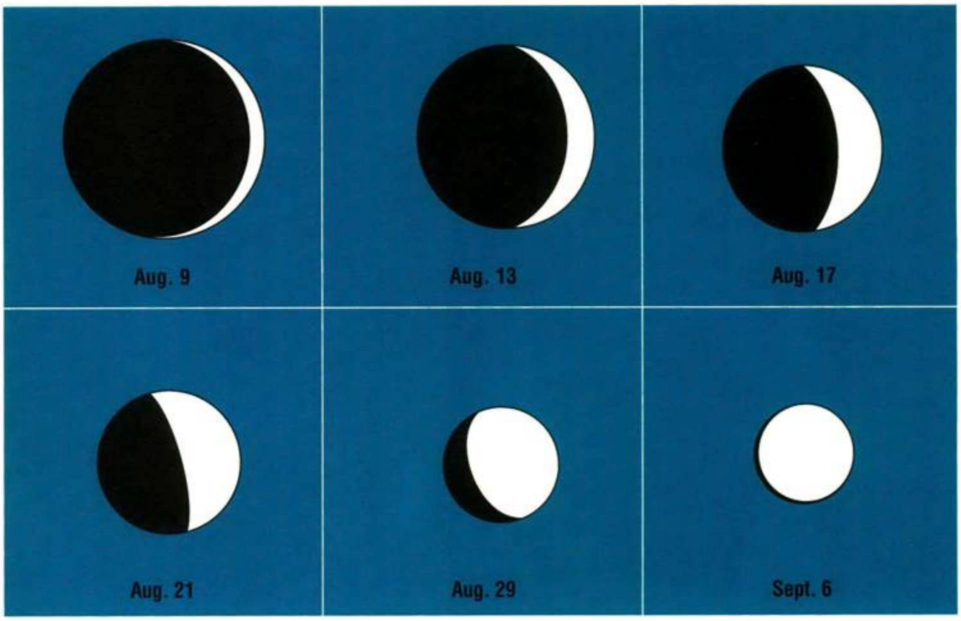
You're probably aware that the Moon rotates on its axis in the same time it takes to revolve around Earth. Thus, we always see the same half of the Moon, regardless of where the Moon is in its orbit.

But that's not the whole story. The Moon's orbit around Earth is an ellipse and, following the laws of planetary motion, our satellite moves fastest when it is closest to Earth and slowest when it is farthest away. On the other hand, the Moon rotates at a constant speed. The result of the uniform rotation and nonuniform revolution is that the Moon appears to wobble a bit as it orbits Earth. This wobble, called libration, allows us to see an enormous impact structure, the exquisite Mare Orientale, which is located right on the "edge" of the visible Moon.

To see Mare Orientale, you must observe the Moon on one of the four or five nights around Last Quarter phase on August 21. The night of Last Quarter gives maximum exposure to the feature. After that, the Moon starts to rotate it away from you. Observing night after night will allow you to see the effects of libration, as the features "roll" over the limb of the Moon.

Mare Orientale appears just beyond two ranges of mountains located very near the western edge of the Moon, just south of the dark crater Grimaldi and closer to the limb. The easier of the two ranges to see is the Cordillera Mountains. Closer to the limb, you'll find the Rook Mountains. Beyond the Rook Mountains is the inner basin itself.

Spacecraft photos reveal that Orientale is the product of an impact by a large body. It appears as a giant rocky bull's eye, with the Rook and Cordillera Mountains defining the successive rings of the eye. Although it's hard to see Orientale from Earth, this feature is a good test of your observing skill. Good luck.



MERCURY'S SIZE AND PHASE change rapidly during this month's morning apparition. Watch in your telescope as the innermost planet's apparent diameter shrinks and its phase waxes.

TELESCOPIC PLANETS

Mercury reaches greatest elongation on August 21, when it lies 18° west of the Sun. Though this is a favorable morning apparition — the ecliptic points nearly straight up from the eastern horizon before dawn at this time of year — you won't have much time to observe the innermost planet. Look just a bit north of due east and some 11° above the horizon 30 minutes before sunrise. If you follow Mercury from mid-August to early September, you'll see the planet shrink in size while the lit part of its disk grows.

Beyond their grand conjunction on August 22, **Venus** and **Jupiter** offer little to telescopic observers this month. Both appear low in the evening sky after sunset and thus are visible only through lots of Earth atmosphere. The good news is that Venus is improving and by late fall will be a fine evening object. The bad news is that Jupiter will disappear into the Sun's glare in early September.

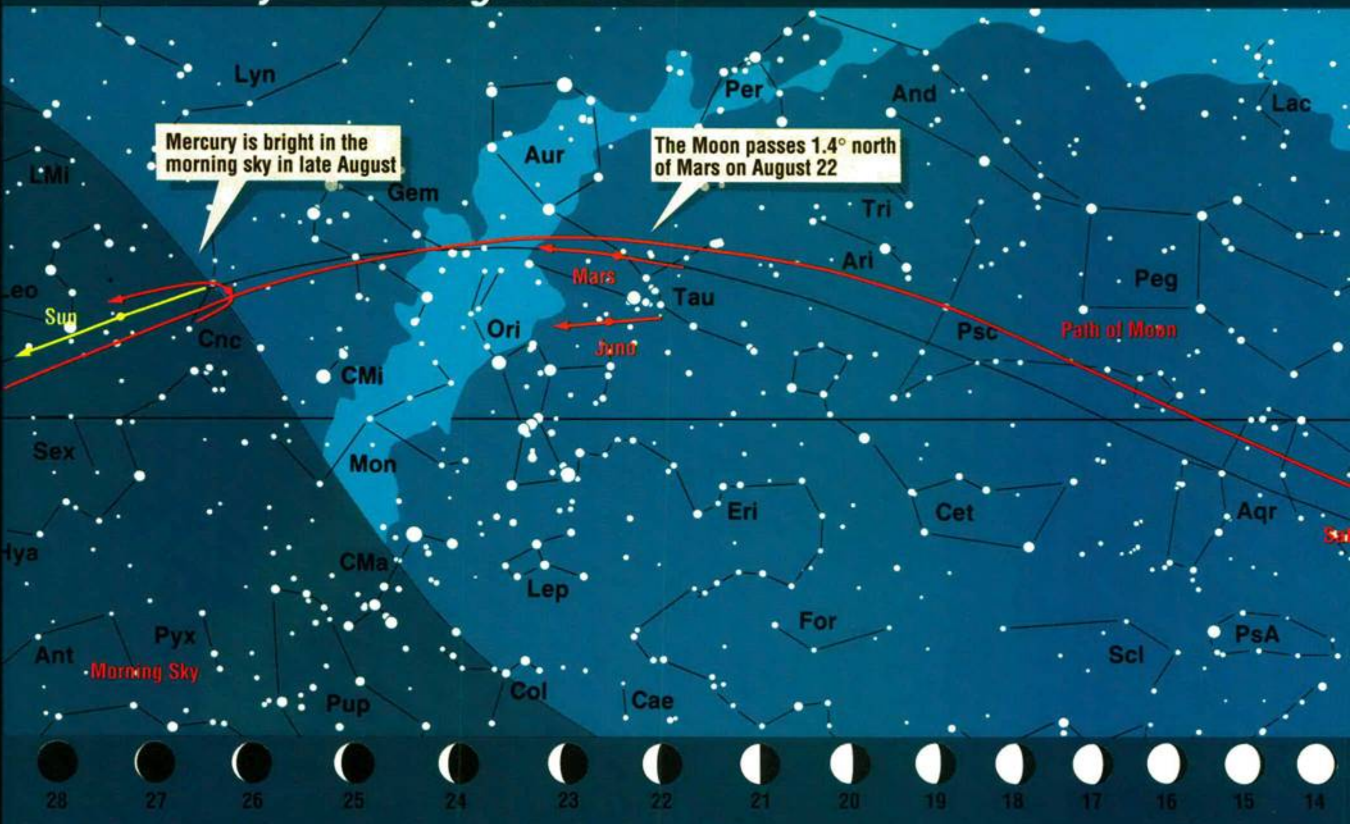
Uranus and **Neptune** remain in Sagittarius, where they've been for the past several years. Both are well positioned for observing this month because they were at opposition in July. For details on how to find these remote worlds and observe their faint satellites, see "Primetime for Uranus and Neptune" on page 68.

COMETS IN THE EYEPIECE

August finds **Comet Shoemaker-Levy** at the end of its visibility for Northern Hemisphere observers. You can find the 7th-magnitude comet in northwestern Virgo during the first week of the month, but the encroaching Moon and the comet's rapid plunge southward take it out of view by mid-month. See "Summer's Gift to Comet Observers" in the July issue for more details on seeing this celestial visitor. □

Rick Shaffer is an engineer and writer in the aerospace industry in Southern California.

The Solar System August 1992


Lyn
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Aur
Gem
Tri
Ari
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Leo
Sun
Mars
Tau
Cnc
Ori
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Psc
Path of Moon
CMi
Sex
Mon
Eri
Cet
Aqr
Hya
CMa
Lep
For
PsA
Pyx
Scl
Ant
Morning Sky
Pup
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Cae
28
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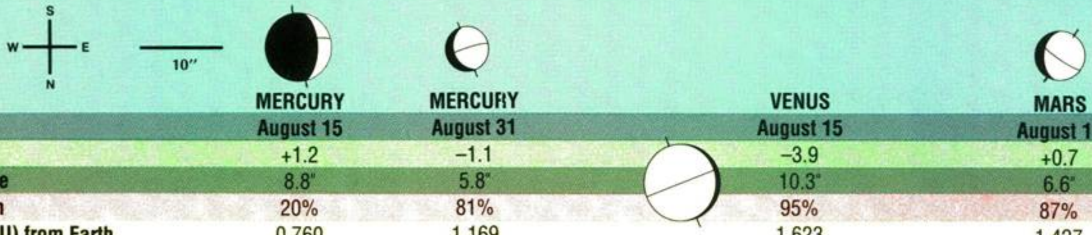
14

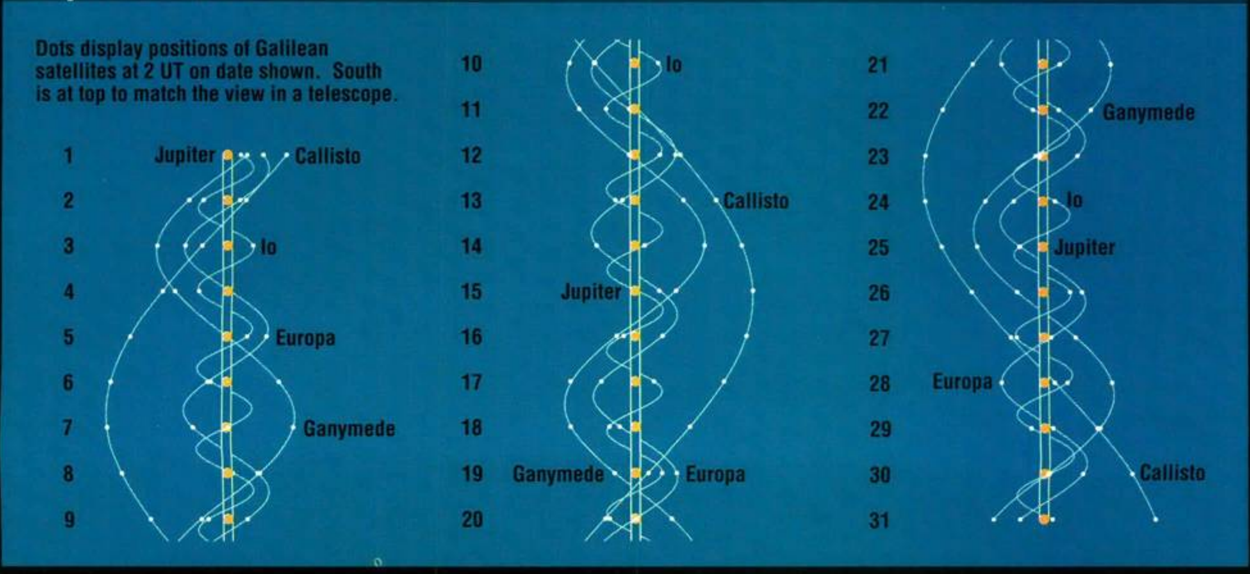
Mercury is bright in the morning sky in late August

The Moon passes 1.4° north of Mars on August 22

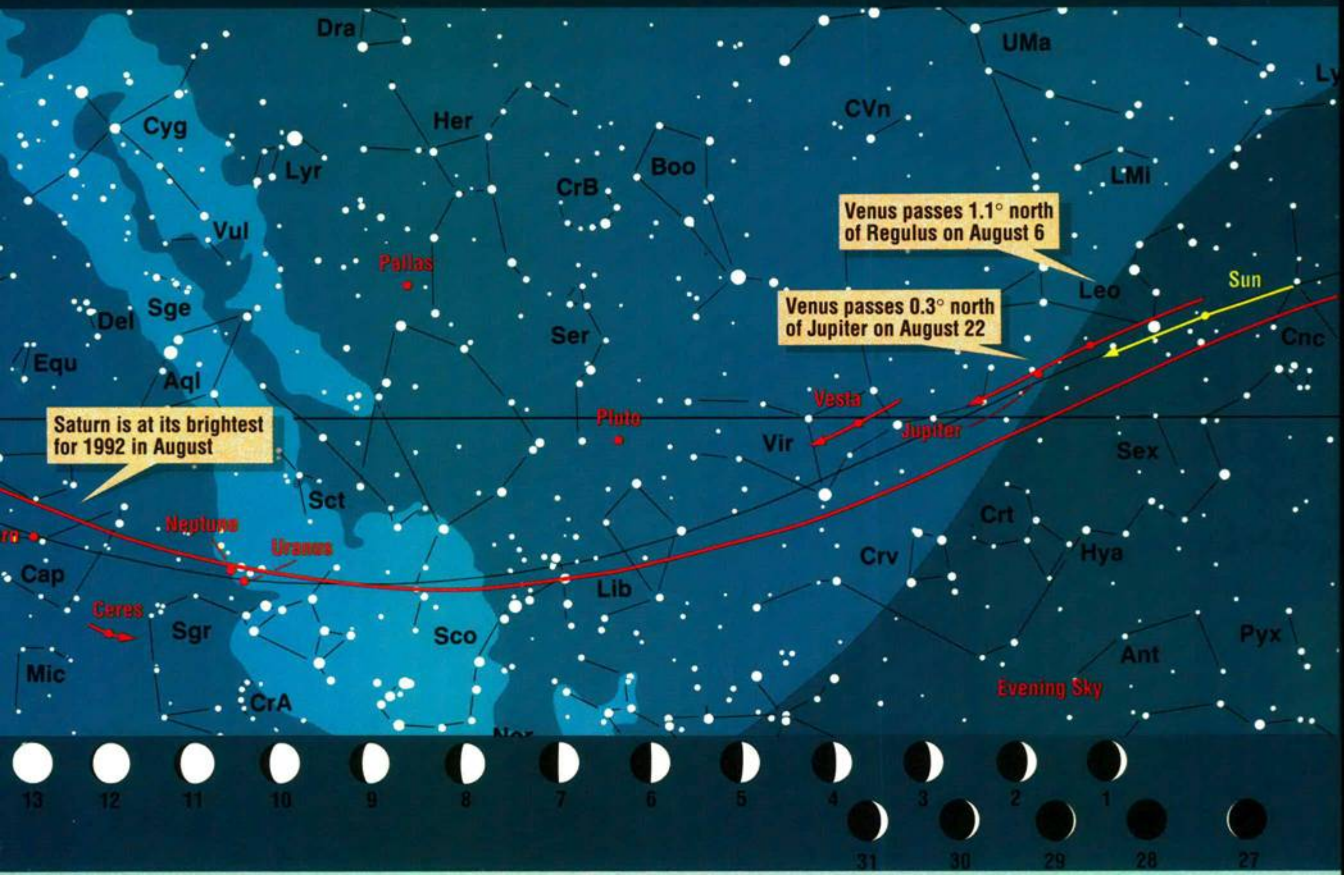


Planet	MERCURY	MERCURY	VENUS	MARS
Date	August 15	August 31	August 15	August 15
Magnitude	+1.2	–1.1	–3.9	+0.7
Angular Size	8.8″	5.8″	10.3″	6.6″
Illumination	20%	81%	95%	87%
Distance (AU) from Earth	0.760	1.169	1.623	1.427
Distance (AU) from Sun	0.356	0.309	0.720	1.434
Right Ascension (2000.0)	8h32.1m	9h46.9m	10h46.9m	4h46.0m
Declination (2000.0)	16°18′	14°44′	9°18′	21°46′

Jupiter's Moons



Dots display positions of Galilean satellites at 2 UT on date shown. South is at top to match the view in a telescope.


Dra
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CVn
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Boo
CrB
LMi
Vul
Pallas
Leo
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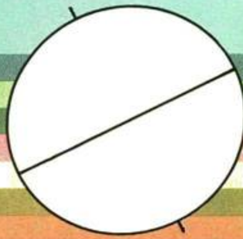
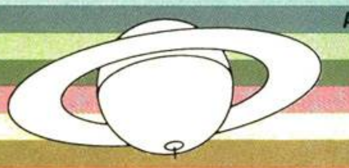
Sge
Ser
Cnc
Equ
Aql
Vesta
Pluto
Vir
Jupiter
Sex
Sct
Crt
Neptune
Uranus
Crv
Hya
Cap
Lib
Ceres
Sgr
Sco
Pyx
Ant
Mic
CrA
Evening Sky
13
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27

Venus passes 1.1° north of Regulus on August 6

Venus passes 0.3° north of Jupiter on August 22

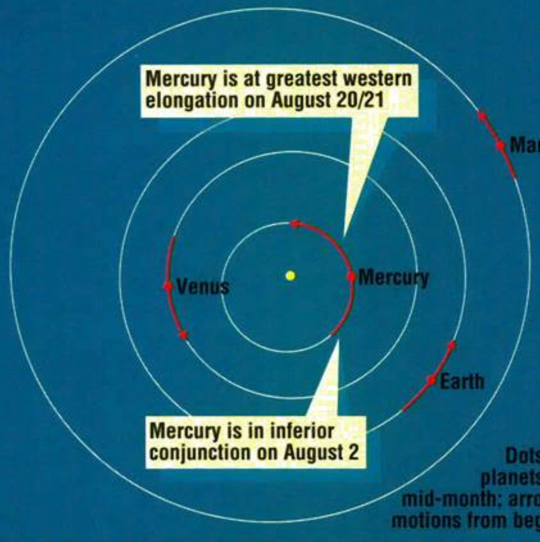
Saturn is at its brightest for 1992 in August





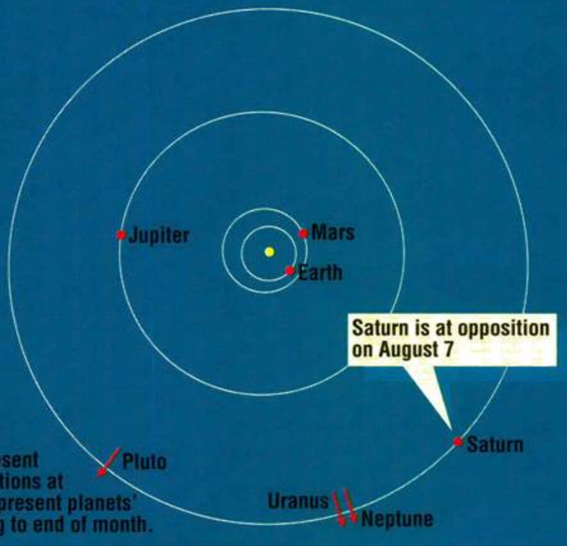
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 15	August 15	August 15	August 15	August 15
−1.7	+0.2	+5.6	+7.9	+13.7
31.1"	18.6"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%
6.329	8.889	18.738	29.363	29.727
5.432	9.894	19.549	30.190	29.706
11h17.6m	21h09.8m	19h04.2m	19h12.3m	15h27.0m
5°43'	−17°25'	−23°03'	−21°39'	−3°41'

The Planets in Their Orbits


Mars
Venus
Mercury
Earth

Mercury is at greatest western elongation on August 20/21

Mercury is in inferior conjunction on August 2


Jupiter
Mars
Earth
Saturn
Pluto
Uranus
Neptune

Saturn is at opposition on August 7

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

PRIME TIME FOR URANUS AND NEPTUNE

This summer is the perfect time to spot two remote worlds and their elusive satellites.

By Richard Talcott

Uranus and Neptune remain linked in the minds of many backyard astronomers. These two gaseous worlds are more nearly alike than any other pair of planets: they have similar size, mass, and composition, and even glow with the same subtle shade of blue-green. The twins of the outer solar system also share an historical link — they were the first planets discovered since antiquity.

Now Uranus and Neptune are linked observationally as well. In 1992 and 1993, the two planets appear closer to one another than at any time in the past 170 years. When they last appeared so near each other in the sky, James Monroe occupied the White House. No one recognized the significance of this meeting, however, because Neptune would not be discovered for another 25 years.

Today, everyone with an interest in observing recognizes the rarity of this planetary meeting. And best of all, nearly everyone with a desire to see the twin planets has the capability to do so. Uranus and Neptune can be seen easily in nothing more sophisticated than a pair of binoculars. And Uranus can be glimpsed with the naked eye if you know precisely where to look.

Two in a Teapot

It's easy to find the general vicinity of the two planets — several bright stars and two easily recognized star patterns lead you right to the area. The hard part is pinpointing which of the myriad points of light are the planets. Uranus and Neptune lie among the background stars of Sagittarius near the eastern edge of the Milky Way, one of the more densely populated regions of the entire sky. Stars abound in this region, and differentiating the planets from the stars takes some effort.

First, find the famous Teapot asterism in Sagittarius with your naked eye. This group of nine 2nd- and 3rd-magnitude stars lies in the south when darkness falls in August. Next, locate the group of three stars located about 5° above the "handle" of the teapot. This triangle of stars — Pi (π), Omicron (o), and Xi^2 (ξ^2) Sagittarii — is your jumping-off point for Uranus and Neptune.

To spot the planets, you'll want to view with binoculars and use the map on the opposite page as a reference. The map shows the position of both planets at 15-day intervals from mid-July to mid-September. (Neither planet moves much in late September, so you can use the September 15 position to get to the right spot.)

Now zero in on Omicron Sagittarii. This 4th-magnitude star is the southernmost one in the stellar triangle. Uranus lies just over 1° due south of Omicron around mid-August. At magnitude 5.6, Uranus is significantly brighter than any star in its immediate vicinity. Once you've spotted Uranus in binoculars, set them aside for a moment and look for the planet with your naked eye. If you have good eyesight and observe from a dark site, you should be able to spot it. If you don't see it, look a bit to the side of the planet's position. This uses the more light-sensitive rods in your eyes, which could make the difference between seeing it and not seeing it.

Once you've found Uranus, shift your attention to Neptune. Go back to Omicron and scan due east. In mid-August, you'll find the planet 2° east of the star. Glowing softly at magnitude 7.9, Neptune is a full magnitude brighter than the faintest stars shown on the map at right. That allows you to pinpoint Neptune by comparing its position to that of the background stars on the map.

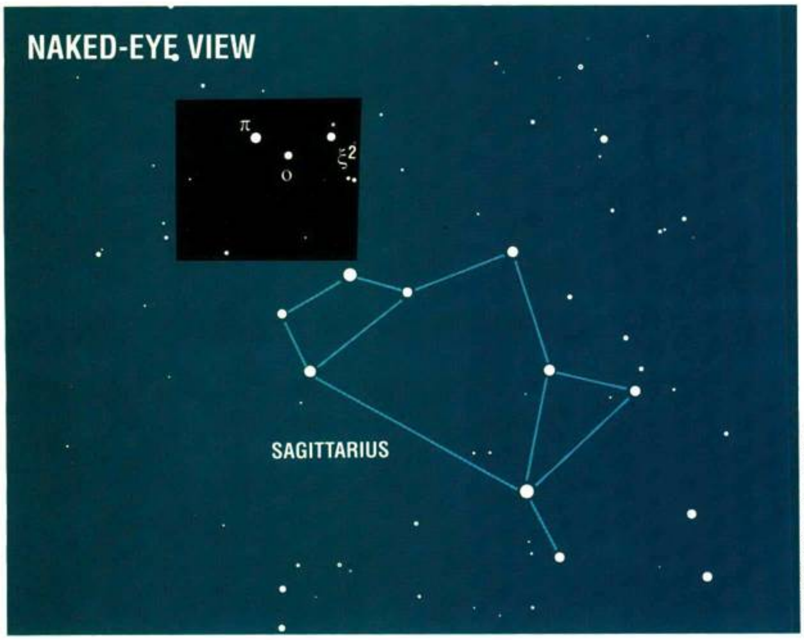
If you're still unsure whether you've seen the planets, the easiest way to confirm your sightings is with a telescope. Center each object in the scope's field of view; then insert a high-power eyepiece. If the object appears as a small disk and not a point of light, then you're looking at a planet.

PLANET FACTS

Planet	Average Distance from Sun	Period of Revolution	Mass (Earth = 1)	Period of Rotation	Diameter	Apparent Diameter at Opposition	Magnitude at Opposition
URANUS	2.869 billion km	84.0 years	14.50	15.6 hours	51,100 km	3.8"	5.6
NEPTUNE	4.497 billion km	164.8 years	17.20	18.4 hours	50,500 km	2.3"	7.9

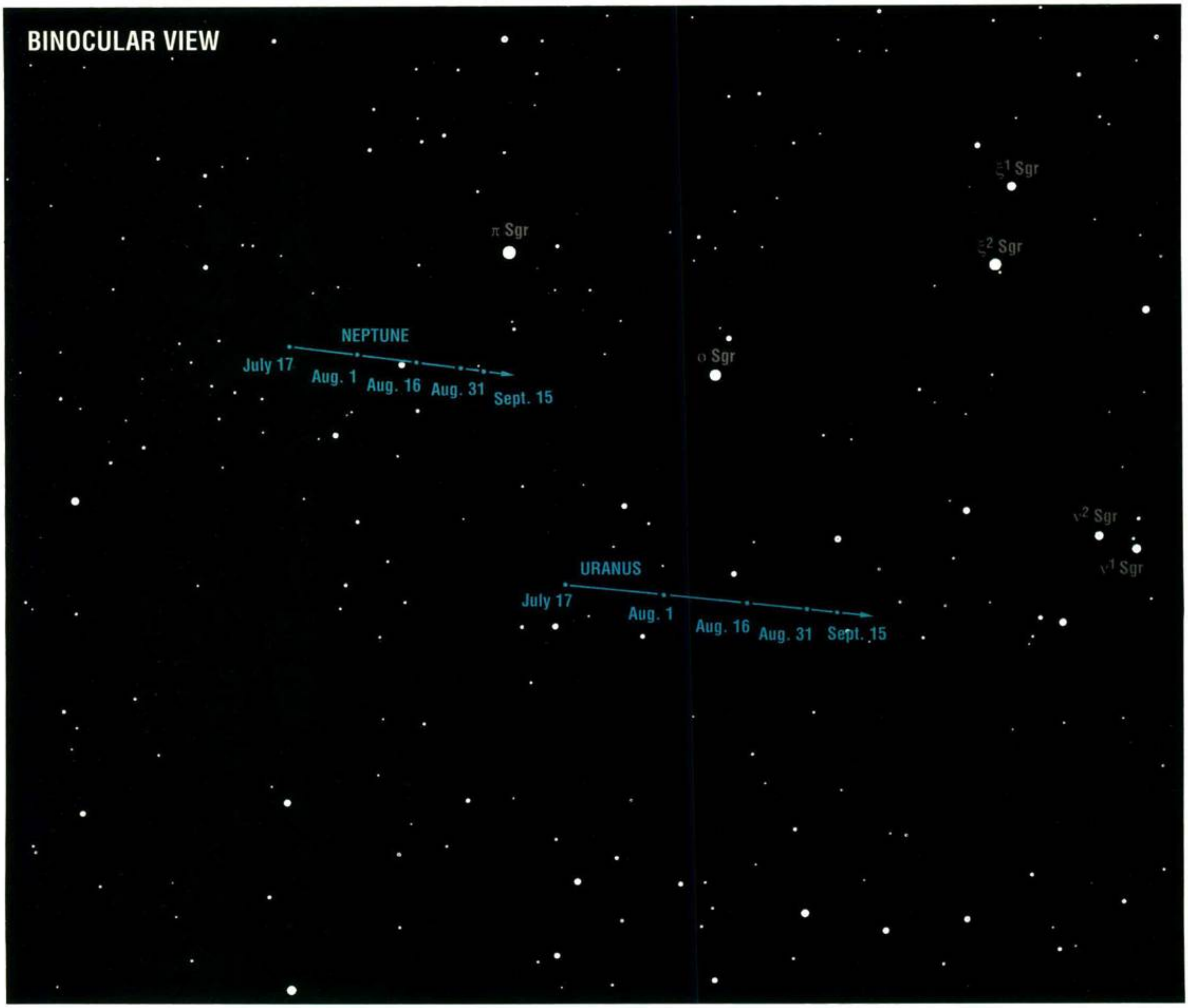
SATELLITE FACTS

Satellite	Average Distance from Planet	Maximum Separation from Planet	Period of Revolution	Mass (Planet = 1)	Diameter	Magnitude at Opposition
TITANIA	435,900 km	33"	8.706 days	0.000068	1,580 km	13.7
OBERON	583,500 km	44"	13.463 days	0.000069	1,520 km	13.9
TRITON	354,800 km	17"	5.877 days	0.000209	2,700 km	13.5


NAKED-EYE VIEW
π
o
ξ2
SAGITTARIUS

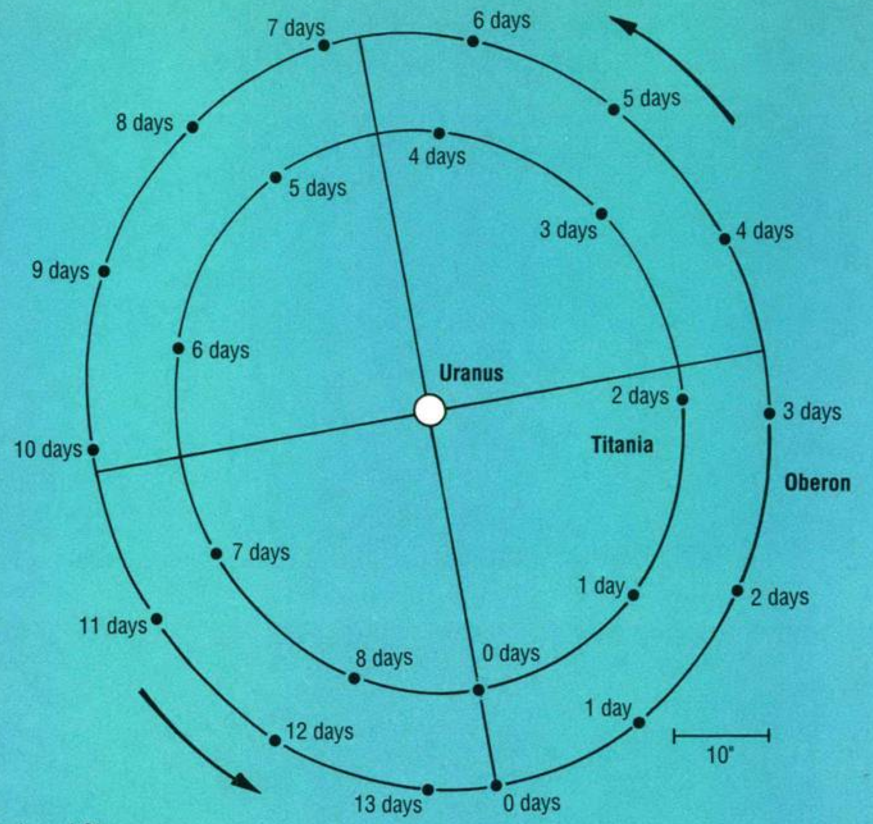
ASTRONOMY: Lee Vande Visse

DISCOVER URANUS AND NEPTUNE for yourself this summer as the two distant planets move slowly through the northern reaches of Sagittarius.


BINOCULAR VIEW
ξ1 Sgr
π Sgr
ξ2 Sgr
NEPTUNE
July 17
Aug. 1
Aug. 16
Aug. 31
Sept. 15
o Sgr
ν2 Sgr
ν1 Sgr
URANUS
July 17
Aug. 1
Aug. 16
Aug. 31
Sept. 15

ASTRONOMY: Lee Vande Visse

URANUS
AND ITS
MOONS



TITANIA

Date	UT of Northern Elongation
July 12	12.4
July 21	5.5
July 29	22.5
August 7	15.6
August 16	8.7
August 25	1.7
Sept. 2	18.8
Sept. 11	11.8
Sept. 20	4.8
Sept. 28	21.9

OBERON

Date	UT of Northern Elongation
July 12	23.1
July 26	10.5
August 8	22.0
August 22	9.3
Sept. 4	20.3
Sept. 18	7.5

Find Titania and Oberon, Uranus' two brightest moons, by calculating where they'll be at the time you plan to observe and then plotting those positions on the diagram. (See text for details.) South is shown at top and east at right in the diagram to match the view in an inverting telescope.

Satellite	Local Time of Observation		UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Date	Time	Date	Time	Days	Hours
TITANIA								
OBERON								

ASTRONOMY: Thomas L. Hunt

A Trio of Moons

Though you can find Uranus and Neptune without much problem, spotting the satellites of these planets is much more difficult. It's easy to understand why. First of all these satellites are fainter than 13th magnitude. That means you need the light-gathering power of an 8-inch telescope to have much hope of seeing them. (A 10-inch or larger scope makes the task easier, though even with a scope that big it isn't easy.) Second, none of the brighter satellites of these planets orbit far from the host planet, so they never fully escape the glare of their planets.

The two brightest moons of Uranus — Titania and Oberon — shine at magnitudes 13.7 and 13.9, respectively. The good news is that these relatively bright satellites are the most distant from the planet. The bad news is that even when their orbits carry them farthest from Uranus, Titania and Oberon never appear more than 33" and 44", respectively, from Uranus. For comparison, Uranus measures 3.8" across.

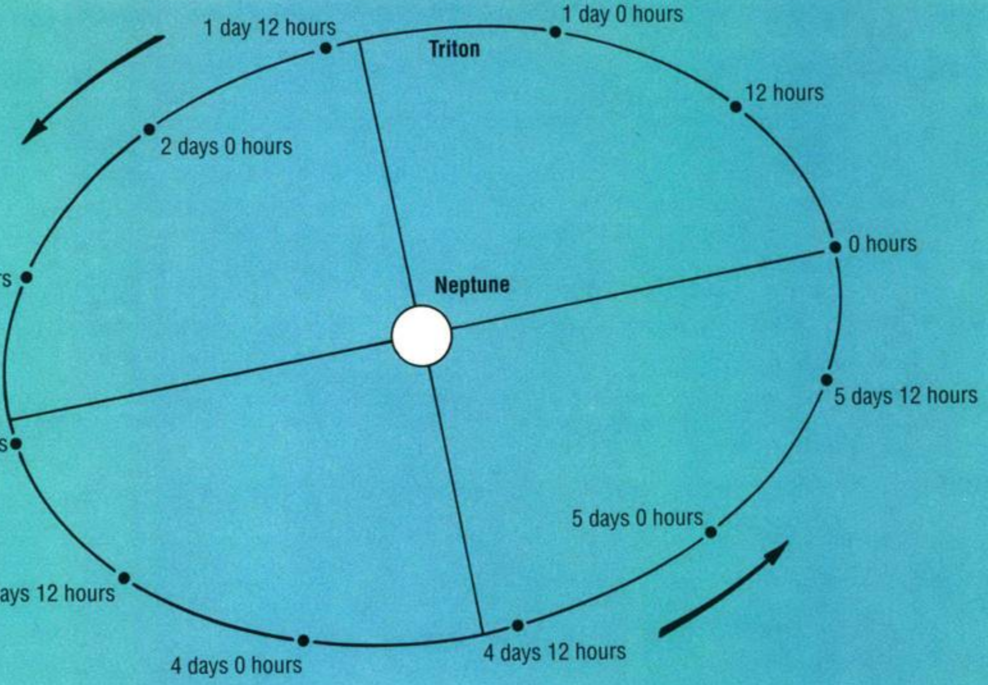
Triton is the only moon of Neptune that can be seen in typical backyard telescopes. This intriguing world, seen up close for the first time when the Voyager 2 spacecraft flew by in 1989, glows at magnitude 13.5. It orbits closer to Neptune than either Titania or Oberon does to Uranus and never appears more than 17" from the 2.3"-diameter planet. However, because Neptune itself is fainter than Uranus, and Triton is slightly brighter than Titania and Oberon, spotting Triton is no more difficult than spotting the Uranian satellites.

The key to finding any of these moons is knowing how, when, and where to look. First, you need an excellent observing site. Because these satellites are faint, you need a dark, transparent sky to spot them. If you typically use more than one observing site, choose the one farthest from city lights.

You'll also want a site where the seeing is normally steady. Turbulence in Earth's atmosphere will cause the images of the planets to appear mushy and wash out the faint satellites entirely. You can't control turbulence caused by the weather, except to avoid nights such as those following a frontal passage when the atmosphere is particularly agitated. But you can control turbulence induced by your surroundings. Steer clear of blacktop parking lots, concrete buildings, house rooftops — anything that absorbs the Sun's radiation during the day and gives it off again at night. Instead, pick a large grassy field or a clearing in a forested area for your observing site.

Also avoid the glare from Earth's Moon. The best time to observe is

NEPTUNE
AND
TRITON



TRITON

Date	UT of Eastern Elongation
July 11	2.0
July 16	23.1
July 22	20.2
July 28	17.4
August 3	14.5
August 9	11.6
August 15	8.8
August 21	5.9
August 27	3.0
Sept. 2	0.1
Sept. 7	21.2
Sept. 13	18.3
Sept. 19	15.3
Sept. 25	12.4

Neptune's brightest moon is Triton, and you can determine its position with the same method you use to find Titania and Oberon (see opposite page and text for details).

Satellite	Local Time of Observation		UT of Observation		UT of Previous Elongation		Difference	
	Date	Time	Date	Time	Date	Time	Days	Hours
TRITON								

ASTRONOMY: Thomas L. Hunt

when the Moon is out of the sky, usually within a week or so of New Moon. This summer, New Moons occur on July 29, August 27/28, and September 26.

Track 'em Down

Now you're all set to observe the satellites of Uranus and Neptune. All you need to do is follow the simple five-step process described below using the worksheets shown on these two pages. (You can avoid defacing the magazine by making photocopies.)

The first step is to decide when you'll be observing and note that time on the worksheets. Next, convert this time to universal time (UT), the unambiguous system of time reckoning used by astronomers. To convert daylight time to UT, add 4 hours to EDT, 5 hours to CDT, 6 hours to MDT, 7 hours to PDT, 8 hours to Alaska time, and 9 hours to Hawaii time. If you live in an area that remains on standard time during the summer, add one more hour.

Next, you need to figure out where each satellite lies at the UT you just calculated by figuring how far in its orbit the moon has traveled since its last elongation. The tables above list the universal times of all the satellites' greatest elongation from mid-July to the end of September. For each satellite, find the most recent elongation and write its time on the worksheet. Then subtract this time from the UT at which you'll be observing. The resulting elapsed time goes in the last column of the worksheet.

The elapsed time specifies where the satellite lies in its orbit. Locate that time on the corresponding orbital diagram and mark the position. (In most cases, you'll have to interpolate between the labeled times to get the appropriate elapsed time.) Then repeat the process for the other two satellites. The resulting diagrams, which show south at top and east to the right, will represent what you'll see through the eyepiece of a Newtonian telescope or a refracting or Schmidt-Cassegrain telescope viewed straight through. If you use a refracting or Schmidt-Cassegrain telescope with a star diagonal, where north appears at top and east to the right, copy the resulting diagram onto clear acetate or tracing paper and view it from behind with top and bottom reversed.

If you don't see the faint satellites the first time, try again on another clear, dark night. It's not easy to find these moons, and it often takes two or three attempts before success. When you finally do see these remote points of light, you won't be struck by their beauty. But you'll feel a sense of accomplishment that will rival any other you've had in backyard observing. ☐

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4¼" to 5"	74.00	4¼" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00
40mm to 80mm Binoculars - Mounted			$ 92.00 pr.

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3.5" to 4"	76.00	3.5" to 4"	66.00
4¼" to 5"	96.00	4¼" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	119.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
14"	199.00	14"	179.00
40mm to 80mm Binoculars - Mounted			$115.00 pr.

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Aperture	mounted:	Aperture	unmounted:
2.4"	$ 79.00	2.4"	$ 65.00
3.1"	82.00	3.1"	69.00
3.5" to 4"	99.00	3.5" to 4"	79.00
4¼" to 5"	125.00	4¼" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
10"	172.00	10"	152.00
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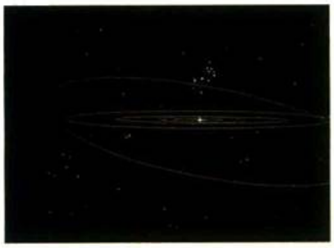
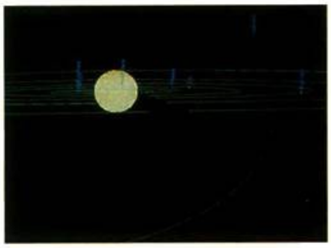
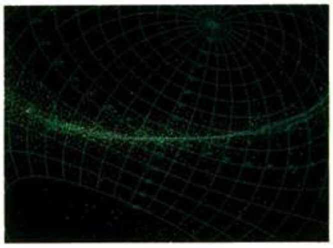


The solar system from 36 light-hours distance.



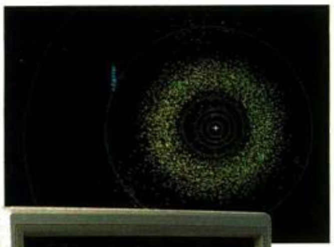
Jupiter expelling comet Lexell from solar system in 1779.

Earth and Moon in Taurus, 16 Oct 2000.

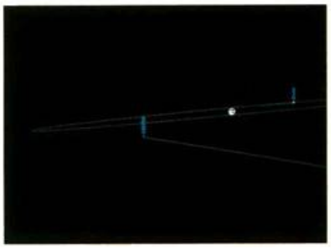


Celestial Skymap with asteroids along the ecliptic.

Polar view of asteroid belt – Jupiter and the Trojan asteroids.



Asteroid 1991BA passing close to Earth. 18 Jan., 17.5h, 1991.



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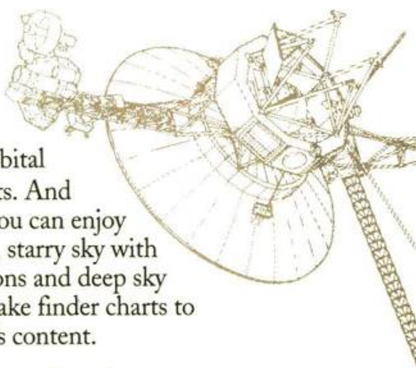

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ASTROPHOTOGRAPHY BASICS

Staging a MOON SHOT

Ready to start shooting pictures through your telescope? The Moon is a great place to start.

by Mark J. Coco

ASTRONOMY: Darla Gawelski

If you're starting out in astrophotography, the Moon is a good target. Compared with most other celestial objects, the Moon has a decided advantage — it's bright! This makes it easy to find and easy to focus on and allows exposures to be short. It also means you can photograph the Moon from a city — no need to worry about light pollution for an object as bright as the Moon.

For lunar photography, as with most astronomical photography, the best camera to use is a 35mm single-lens reflex, or SLR. Hundreds are available on the market today, each loaded with features. But for taking shots through your telescope, the most important feature is a removable lens. The second requirement is that the camera allow you to change shutter speeds with a manual control.

Ideally, the camera also should have mirror lock-up and a self-timer. These reduce camera shake by locking the mirror up out of the way before the shutter is released and by allowing you to keep your hands away from the camera at the moment the shutter opens and closes. Another nice feature is a mechanical shutter, one that operates without the need for battery power. It's a feature you'll appreciate on chilly nights.

Three good mechanical cameras still on the market are the Pentax K1000, Nikon FM2N, and high-end Canon F1. Older cameras that are no longer in production include the Nikon F and F2, Minolta SRT 101, and Olympus OM-1. They can often be found in the used equipment section at your local camera store.

THE MOON IS AN EASY TARGET for starting your astrophotography ventures. To record the gibbous Moon, Andrew Steinbrecher used a 16-inch f/5 Newtonian, Panatomic-X film, and a $^{1}/_{125}$-second exposure.

Three Stages

There are basically three ways to photograph the Moon. The first doesn't even require a telescope. Simply mount a telephoto lens (135mm or longer) on your 35mm camera, attach the camera to a tripod, and shoot. This method is good for shots of the crescent Moon setting in a twilight sky, the Full Moon rising, or other pictorial compositions.

The advantage of this technique is that it couldn't be simpler — literally point and shoot. The limitation is that even with relatively long telephoto lenses (500mm or so), the image of the Moon will be small. To determine the size in millimeters of the lunar image on your frame, divide the focal length of your lens or telescope by 110. A 500mm telephoto will produce a Moon about 4.5 mm across, still a small disk compared with the 24 mm height of the frame.

To reveal individual craters on the Moon, you need to use a focal length longer than 500 mm. This is where your telescope comes in. Even a modest 60mm-aperture refractor usually has a focal length of 700 mm or more.

To shoot through a telescope, we turn to the second technique, "prime focus" photography. Here the camera (with its lens removed) replaces the eyepiece. Your telescope's lens or mirror is the only optics in the system. To do this you need a prime focus camera adapter along with a T-ring to mate your particular camera to the adapter's universal threads. As an option, you can also use a Barlow lens to multiply the focal length of your scope by a factor of two or three, giving you a larger lunar disk.

The third lunar photo technique — eyepiece projection — is also used for shots of the planets. With it you can use your telescope to frame selected areas of the Moon. To achieve this degree of magnification, you need a camera adapter that allows you to place an eyepiece in the telescope-to-camera coupler. The eyepiece projects a highly magnified image of the Moon onto the film frame. This technique multiplies the effective focal length of your telescope by a factor of 10 to 20 — to 20,000 mm or more.

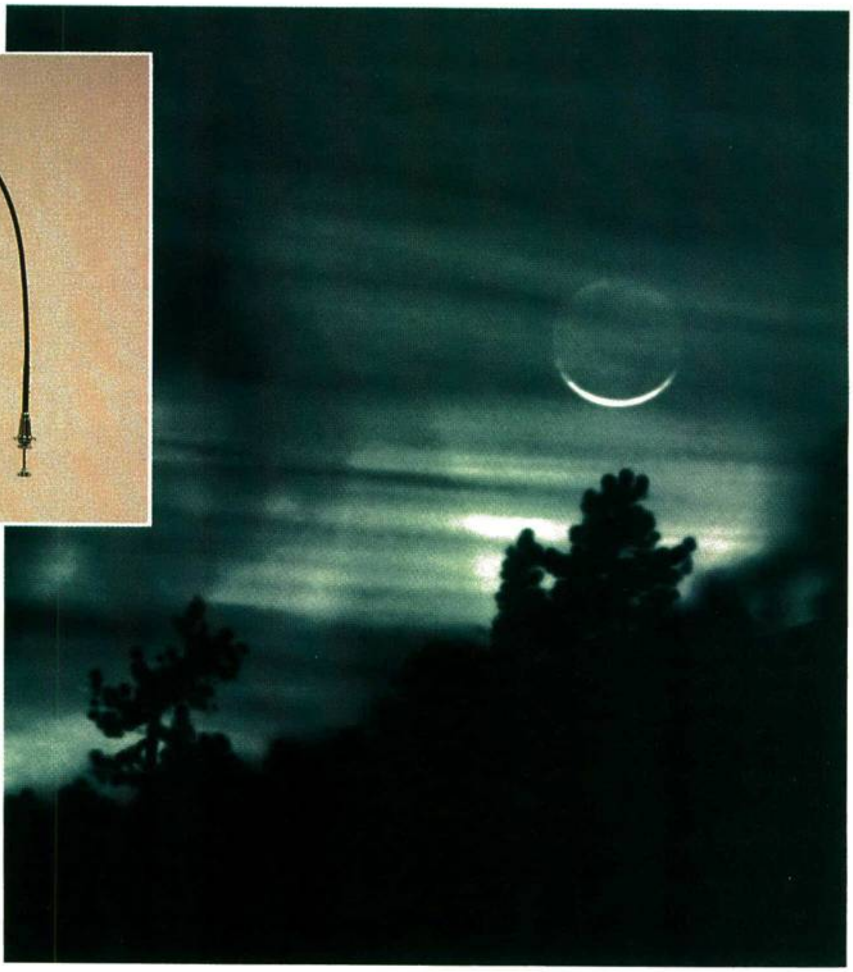
For this last type of high-power lunar photography, you must have a telescope equipped with an equatorial mount and electric clock drive. For prime focus shots of the whole disk of the Moon, if you have an equatorial mount and clock drive, by all means use them — you won't have to keep centering the Moon for each exposure and you'll get the sharpest possible shots.

However, you can still get decent shots of the Moon using an altazimuth-mounted telescope (such as a small refractor or Dobsonian-mounted reflector), or an equatorially mounted scope that lacks a clock drive. Lunar exposures are short enough that the movement of the Moon during the exposure shouldn't impart objectionable blurring, especially if you use fast film (ISO 400 or so) and focal lengths under 1,000 mm.

When to Launch

Because the Moon moves around Earth, it is not always in the same place in our sky. You can find the phase of the Moon for any given date in your local newspaper or in ASTRONOMY each month. As a general rule, the waxing crescent, First Quarter, and waxing gibbous

ASTRONOMY: Darla Gawelski



CATCHING THE THIN CRESCENT MOON requires no more than a telephoto lens and a tripod. Jeffrey Jones used a 200mm f/4 lens, Tech Pan 2415 film, and a 1-second exposure.

MAXIMUM EXPOSURES

If you are using a tripod-mounted telephoto or a telescope without a clock drive, these are the maximum exposures you should use at each focal length. Go longer and the apparent motion of the sky will trail the Moon's image. (Determine the maximum exposure by dividing 250 by the focal length of your telescope.)

Focal Length	Maximum Exposure
500mm	1/2 second
1,000mm	1/4 second
1,500mm	1/8 second
2,000mm	1/8 second
3,000mm	1/15 second

Depending on the f/ratio of your telescope, keeping exposures faster than these limits may require you to use fast films.

phases are visible in the evening sky. The Full Moon is directly opposite the Sun and, therefore, visible all night. To catch the waning gibbous, Last Quarter, or waning crescent, you have to go out late at night or very early in the morning.

While the Full Moon tends to attract the most attention, it is not the best phase to photograph. The side we see is illuminated by direct sunlight, eliminating shadows. The Full Moon looks flat, with low contrast.

The best time to photograph the Moon is during the crescent, Quarter, and early gibbous phases. During these times, long shadows from mountain ranges, crater ridges, and other lunar features create striking contrasts along the terminator, the day/night line on the Moon.

For the sharpest shots, always try to photograph the Moon when it is as far above the horizon as possible. The higher in the sky, the less atmosphere there is to look through, which means an image affected least by turbulence. For thin crescent phases there is not much you can do because the Moon is always low in the sky when the Sun is below the horizon.

Fueling Your Camera

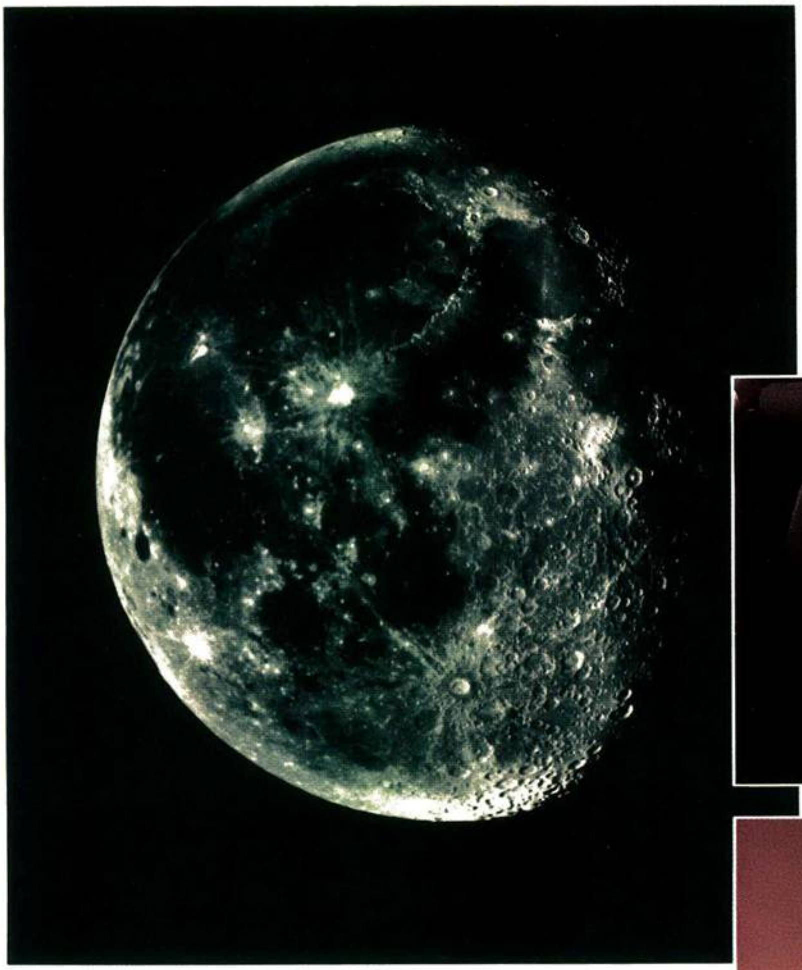
If you are using a clock drive, you're best off using a slow, fine-grained film. With a clock drive, the longer exposures demanded by slow films are no problem. If you are not using a clock drive, then your choice of film depends on the lunar phase. When Full, the Moon is extremely bright, and even slower films offer short exposures. During crescent phases the Moon is dimmer, and faster films are better since they allow shorter exposures.

For color print work, try the Ektar series of films, either ISO 25 or 100. If you prefer color slides, use Kodachrome 25 or 64 or Fuji Velvia. Ektachrome 100X or 100HC are also worth trying, as are comparable speed films from Fuji. For black-and-white photography, try Kodak's T-Max 100, Panatomic-X, or Technical Pan 2415.

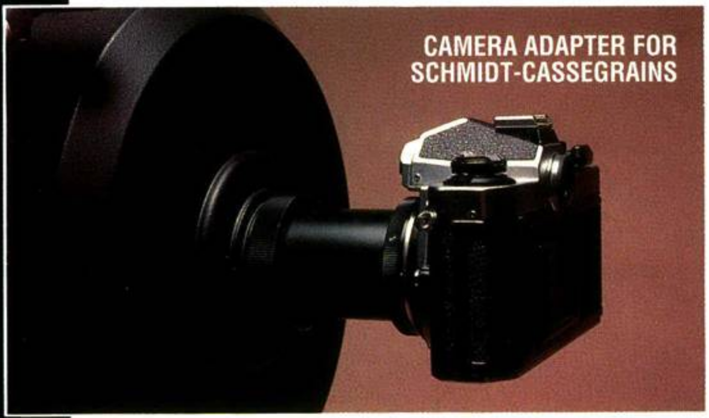
If you need a faster film (for eyepiece projection shots), try Kodachrome 200, Ektachrome 400X, Fujichrome 400, ScotchChrome 400, or any of the ISO 400 color print films.

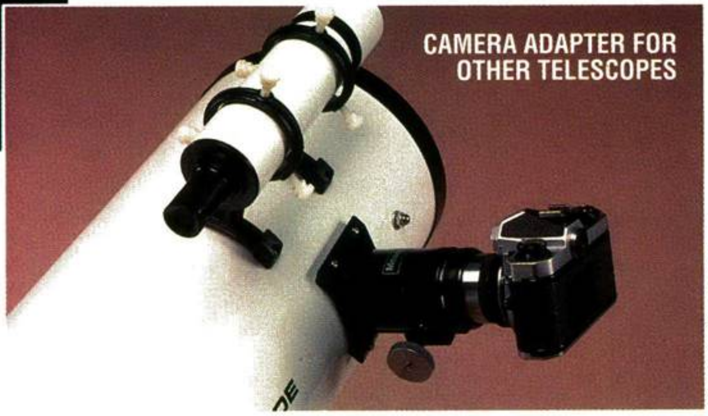
Avoiding Overexposure

When determining exposures, don't use your camera's internal



TO MOVE IN CLOSE, attach your camera to your telescope using the prime focus adapter appropriate for your telescope. You'll then be able to get photos such as Robert Luffel's portrait (left) shot through an 8-inch SCT.





ASTRONOMY: Darla Gawelski

light meter if your telescope has less than 2,000 mm of focal length. Most camera light meters will be fooled by the large area of blackness surrounding the Moon, resulting in an overexposed Moon. If your telescope's focal length is 2,000 mm or more, the Moon almost fills a 35mm's frame and your camera's internal light meter will provide more accurate metering.

For recommended exposures, see the table on page 67. But, whether you determine your exposure from a light meter or from a table, keep in mind that lots of variables other than phase can affect the brightness of the Moon. These include the Moon's altitude and the transparency of Earth's atmosphere. To ensure getting good photos at each shooting session, bracket your exposures — make some longer and some shorter than the recommended time. So, if 1/30 of a second is the recommended exposure, take shots at 1/8, 1/15, 1/30, 1/60, and 1/125 second.

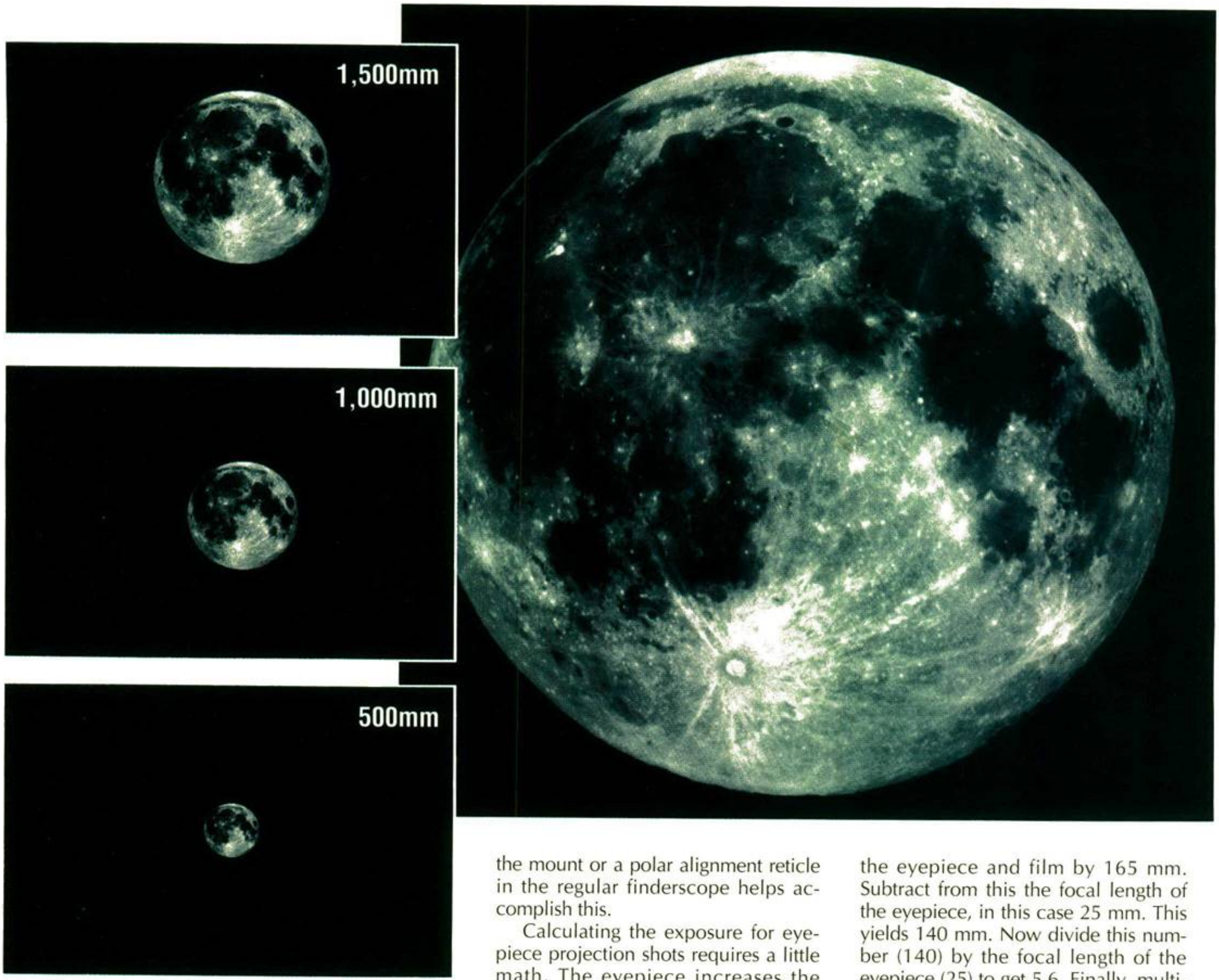
Boosting the Power

To record just a few craters or other lunar features up close, you need the added magnification of eyepiece projection photography, a technique that places additional demands on your equipment and skills.

For example, in addition to the mount and clock drive mentioned earlier, it's best to have a drive corrector that allows you to vary the speed of your scope's drive motor. A slightly slower drive speed, sometimes called the "lunar rate," tracks the Moon with finer precision than a drive operating at the normal sidereal rate.

You should also consider counterweights to balance your telescope. Eyepiece projection adapters can extend quite a distance from the telescope, throwing the scope off balance, producing inaccurate tracking.

And with eyepiece projection, you need to be more concerned about polar alignment. Simply aiming the polar axis roughly at the pole, as can be done for prime focus shots, is not good enough for eyepiece projection. If you can, try to get the polar axis aimed within a few arcminutes of the true North Celestial Pole — the closer the better. A polar alignment scope in



THE SIZE OF THE LUNAR DISK depends on the focal length you use. You can get frame-filling shots using a 2,000mm-focal-length scope such as the 8-inch f/10 SCT used by Brian Tkachyk for the photo at top right. Shorter focal lengths (above) produce proportionally smaller images.

the mount or a polar alignment reticle in the regular finderscope helps accomplish this.

Calculating the exposure for eyepiece projection shots requires a little math. The eyepiece increases the effective f/ratio of the scope so you need to calculate this value before determining your exposure.

Use this formula to determine the effective f/ratio of your telescope during eyepiece projection: *New f/ratio = Telescope's normal f/ratio x [(D–F) ÷ F].*

The telescope's normal f/ratio is its f/ratio at the prime focus. This is simply the scope's focal length divided by the aperture. D is the distance between the focal plane of the eyepiece and the film plane at the back of the camera. F is the focal length of the eyepiece.

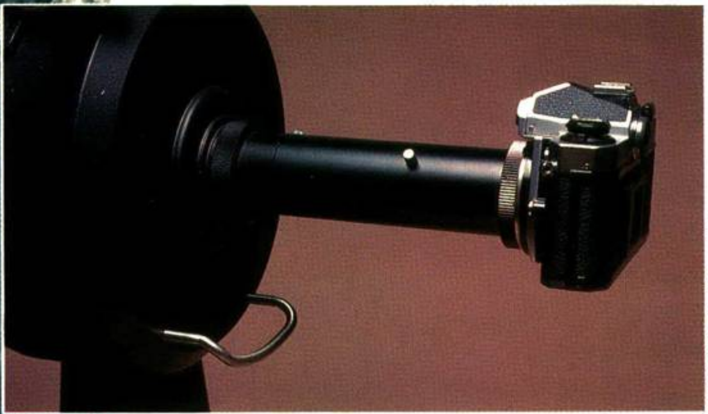
For example, say you have a 5-inch (127mm) f/9 refractor with a focal length of 1,140 mm used with a 25mm eyepiece. First, you will need to determine the distance from the eyepiece to the film plane. This will vary depending on the length of the camera adapter.

For this example, we'll use a commercially made adapter that separates the eyepiece and film by 165 mm. Subtract from this the focal length of the eyepiece, in this case 25 mm. This yields 140 mm. Now divide this number (140) by the focal length of the eyepiece (25) to get 5.6. Finally, multiply this by the f/ratio of the telescope, which is f/9. This yields an f/ratio of 50 for this telescope-eyepiece combination. Use this f/ratio (or the closest one to it, in this case f/44 in our table) when looking up recommended exposures.

Helpful Hints

With both prime focus and eyepiece projection techniques, the trickiest part is focusing. A telescope, unlike a telephoto lens, does not have a pre-set infinity focus. You must look through the camera and turn the telescope's focus knob until the image is sharp. If your camera has a central split-screen focuser, this circle may black out due to the long focal length of your telescope. If this happens, focus off-center on the ground glass portion of your focusing screen.

To help you see the exact point of best focus, use a focusing magnifier. These devices clip onto a camera's viewfinder and make it much easier to tell when the image is in focus.



ASTRONOMY: Darla Gawelski

TO MOVE IN CLOSER, use an eyepiece inserted into a special eyepiece projection adapter (above). For his close-up of Copernicus, Jim Rouse used an 8-inch Newtonian and an eyepiece projection setup that gave an effective f/ratio of f/38. The required exposure was 2 seconds on High Contrast Copy film.

MOON SHOT EXPOSURES

Try the following exposures when photographing different lunar phases with ISO 200 film at various f/ratios. These are based on the easy-to-remember fact that as the Moon waxes in phase, it doubles in brightness at each successive phase. For example, a wide crescent Moon is twice as bright as a thin crescent Moon and requires half the exposure time.

f/ratio	Thin Crescent	Wide Crescent	Quarter	Gibbous	Full
5.6	1/60	1/125	1/250	1/500	1/1000
8	1/30	1/60	1/125	1/250	1/500
11	1/15	1/30	1/60	1/125	1/250
16	1/8	1/15	1/30	1/60	1/125
22	1/4	1/8	1/15	1/30	1/60
32	1/2	1/4	1/8	1/15	1/30
44	1	1/2	1/4	1/8	1/15
64	2	1	1/2	1/4	1/8
88	4	2	1	1/2	1/4
100	6	3	1.5	1	1/2

For films other than ISO 200:

- For ISO 100 films, double the exposure times (1/4 second becomes 1/2 second).
- For ISO 50 films, multiply exposures by 4 (1/4 second becomes 1 second).
- For ISO 400 films, exposures are one-half those recommended.

To reduce vibration, use a cable release when tripping the shutter. Better yet, use the self-timer on your camera. Center the Moon and focus as usual. Once you are ready, cock the shutter, set the timer and release it, and then stand back. The few-second wait before the shutter fires will allow vibration to die down.

If the exposures called for are longer than 1/2-second, then cover the front of the telescope with a dark card, lock the shutter open on B, wait a few seconds for the vibration to die down, and then make the exposure by flipping the card away and then back. Then close the shutter. This "hat trick" method is by far the best way to get long-exposure Moon shots free of vibration-induced blurring.

When using long focal lengths, nights of steady air (or "good seeing" as it's called) will give best results. Turbulence in the upper atmosphere can degrade fine detail and take the edge off what would otherwise be a sharp photo. Slight wind can also cause enough vibration to smear your photos. Always wait for the wind to die down before tripping the shutter.

When starting out, always keep accurate records for each roll of film. Record the date, telescope, exposures, eyepiece, f/ratio, film, and some comments on the seeing conditions. Those notes are your best teaching tool.

A final tip: start with tripod and prime focus shots of the Moon. This will get you good results in your first rolls of film and will inspire you to try more advanced techniques like eyepiece projection. Before long, you'll be a master at staging Moon shots. ☐

Mark J. Coco is a technical writer and amateur astronomer living in Redondo Beach, California.

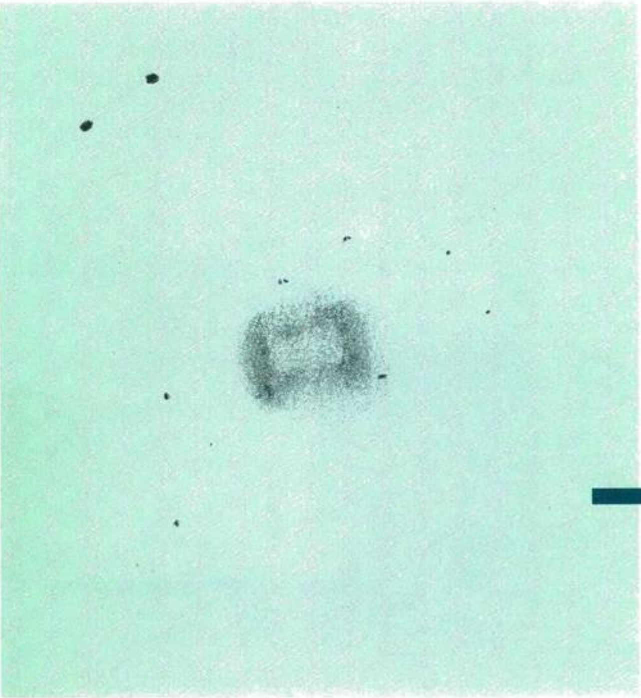
OBSERVING BRIGHT PLANETARY NEBULAE IN SAGITTARIUS

Tracking down and observing these small remnants of exploded stars will introduce you to the main drag of the Milky Way.

by Richard W. Jakiel

Sagittarius is a constellation that seems to have it all. Filled with bright stars, graced with the glow of the Milky Way's central bulge, and packed with bright deep-sky objects of every kind, the celestial archer is a favorite attraction for observers who want to kick the summertime blues. Yet the great star group holds a lesser-known collection of objects that few observers — even dedicated deep-sky buffs — have seen, namely planetary nebulae.

Planetary nebulae are the remnants of dead stars that ran out of hydrogen fuel to burn and gently expelled their gases into the surrounding volume of space. They are visible in scopes as gently glowing disks of blue-green light (much like the planets Uranus and Neptune) — hence the name planetary nebulae. Most observers have seen the brightest such objects, the Ring Nebula in Lyra and the Dumbbell Nebula in Vulpecula, but they have ignored the planetaries of Sagittarius because of larger neighbors like star clusters and emission nebulae.



NGC 6445

20-inch f/4.5 reflector

315x with UHC filter

by Richard W. Jakiel

A look at Tirion's *Sky Atlas 2000.0* reveals the positions of a dozen planetaries in Sagittarius, and the more detailed *Uranometria 2000.0* shows well over one hundred. Many of these are faint objects from the Perek-Kohoutek catalog of planetaries. These are primarily low surface brightness objects that are often difficult to see even in a large scope. However, more than one dozen planetaries in the constellation are bright enough to see with any telescope.

Such is the case with **NGC 6445**, located near the Sagittarius-Ophiuchus border. As planetaries go, this is an easy object to find, lying 2° southwest of the open cluster M23. It is 5' west of a 7th-magnitude star and 20' north of the faint globular cluster NGC 6440. NGC 6445 glows at magnitude 11.0 and is large, measuring 38" by 29". In my 8-inch scope at 158x, the nebula looks like a glowing oval disk with a hint of annularity. I can see subtle knots and condensations across its surface. Large scopes with nebula filters reveal a more detailed image. With a 20-inch scope at 315x and a UHC filter, NGC 6445 appears like a crushed box. The outer rim shows bright knots and an outer surface peppered with faint wisps of nebulosity. The central part of the box is partly illuminated and shows slight surface variations and wispy strands of nebulosity.

NGC 6445

Mag 11.0

Size 38" by 29"

by Jack B. Marling

NGC 6565, a small, bright planetary, is more typical of its class. Find this object by moving 2.5° northeast from Gamma Sagittarii; a chain of stars makes the task relatively easy. This object measures only 10" by 8" but it glows at magnitude 11.6, so it has high surface brightness. At low powers, NGC 6565 looks like a slightly bloated star with a greenish hue. High powers with a medium-sized scope reveal structural details. With my 13-inch scope at 269x, I see a tiny ring nebula much like the famous example in Lyra. The central perforation is only about 4" across. While you're in the neighborhood, use low power to scan the area around B90, a small dark nebula only 20' to the west. It is small and fairly distinct and provides a good break from high-power observing.

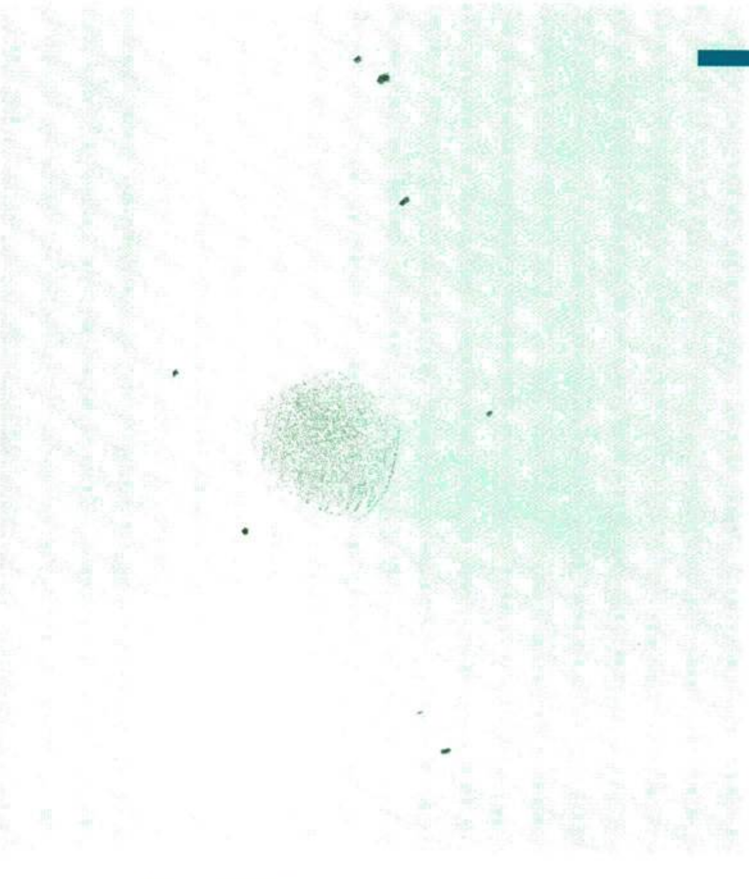
Farther south lies the largest bright planetary in Sagittarius, **NGC 6563**. Measuring a hefty 54" by 41", it is fairly easy to pick out of the rich star field even at low powers. Its faint greenish glow registers at magnitude 11.0, making it a challenging object due to low surface brightness. I find it by star-hopping from Epsilon Sagittarii. First I move 30' north and sweep 3° west until a small triangle of 7th-magnitude stars comes into view. NGC 6563 is a low surface brightness object, being nearly the size of M57 but two magnitudes fainter. Dark skies and the use of a nebula filter will help you see it. An 8- or 10-inch scope helps you discern the oval outline and subtle variations in surface brightness in this object. Larger scopes show the planetary shaped like a polygon. The feeble 15th-magnitude central star is visible only in the largest backyard scopes.

Between the wispy nebulosities of the Lagoon and Trifid nebulae and the Small Sagittarius star cloud lie several moderately bright planetaries. The challenge here is to try to distinguish them from the numerous field stars. The most difficult of these to find is **NGC 6578**, located 1° northeast of Mu Sagittarii and just north of a triangle of 5th- and 6th-magnitude stars. Bright, distinctive guide stars make all the difference in finding small objects like this one, but the glare from Mu may hinder your observations of the nebula. If this happens, place the star outside of the field of view. In my 13-inch scope at 214x, I see a tiny nebulous spot only 9" across. Although it is pretty faint with a magnitude of only 12.9, the fuzzy appearance and greenish glow of the nebula distinguish it from the surrounding stars.

NGC 6537 and **NGC 6567** challenge us because of their location in dense star fields. They are each a magnitude or so brighter than NGC 6578, but the fields in which they lie are rich and confusing. Using Mu Sagittarii as your starting point, star-hop north about 1°, then sweep west 2.5°. The hopping can be tricky, so consult your finder chart and take your time. You'll find NGC 6537 only about 5' southwest of a 7th-magnitude star. It measures only 10" across, about half the size of Saturn's globe. Glowing at magnitude 11.6, it is nonetheless a moderately bright member of its class. Small- to medium-sized scopes have little problem showing the small round disk. With a large backyard scope in dark skies, it may be possible to glimpse the faint outer ring that surrounds the inner nebulosity around NGC 6537.

Lying off the southwestern edge of the Small Sagittarius star cloud is the 11th-magnitude planetary NGC 6567. Due to the rich field and the nebula's small size, this object is difficult to pick out. Once the scope is in the right area, switch to higher power. This object is oval and measures 11" by 7" across. Because a 12th-magnitude star lies off the planetary's eastern edge, the two together appear like a fuzzy double star. The small greenish disk is easy to see with a small scope, but the central star glows faintly at magnitude 14.4, making it difficult to pick out. After observing this tiny nebula, take some time to sweep around this region. This is one of the richest star fields visible in the northern sky; it offers a pleasant change of pace from high power viewing.

Sweeping southeastward from M24 toward the

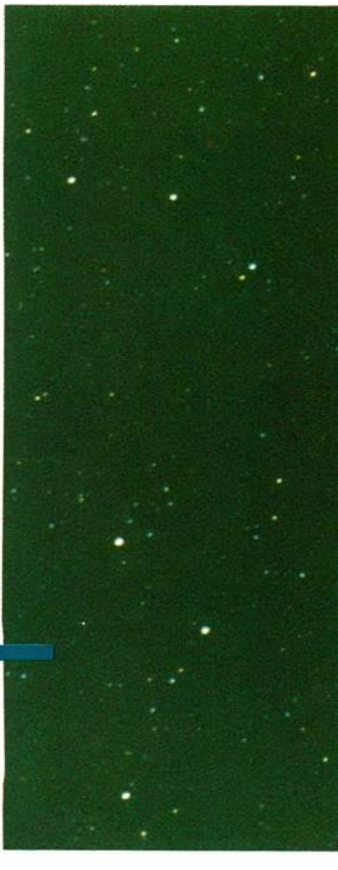


NGC 6563

20-inch f/4.5 reflector

175x

by Richard W. Jakiel

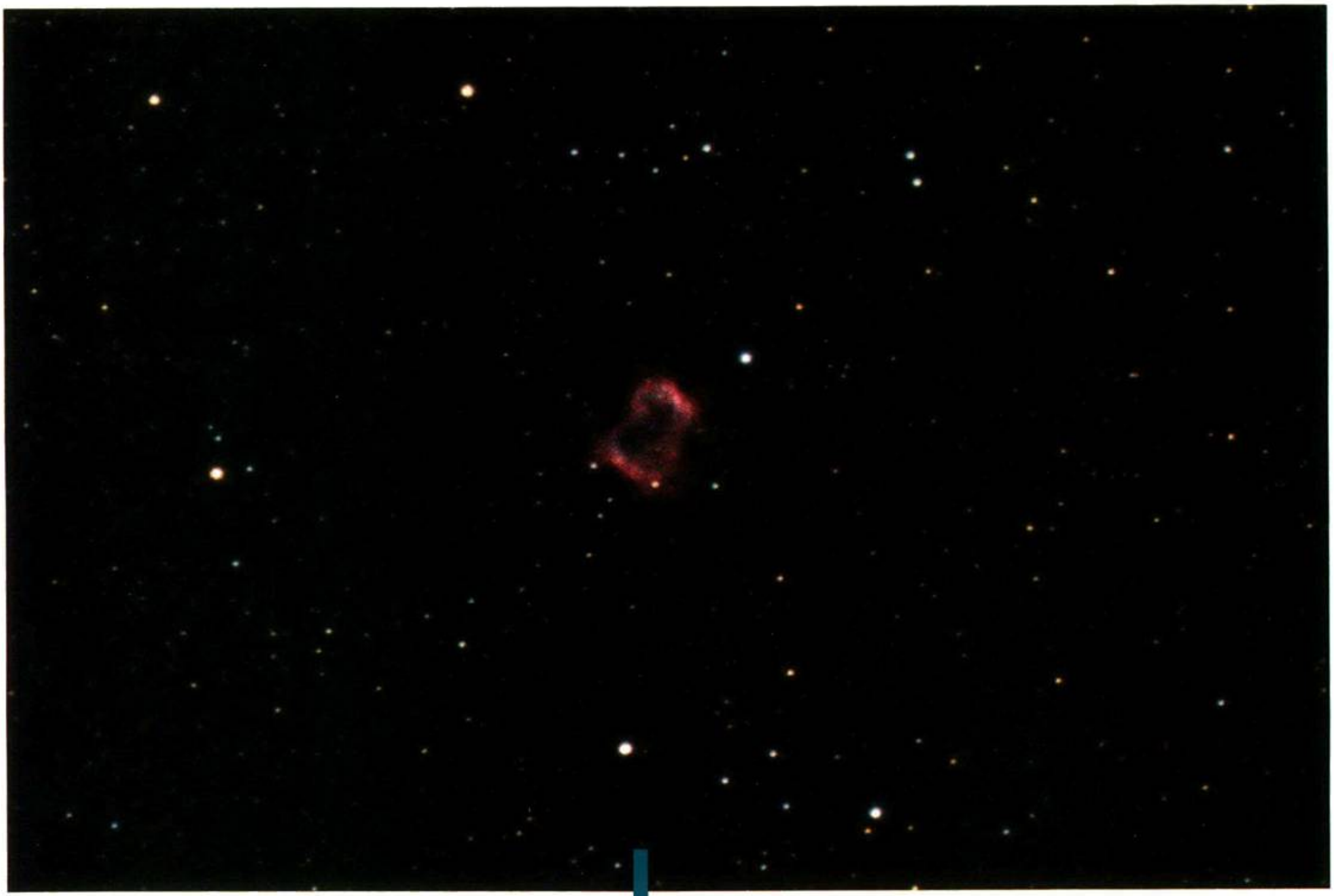


NGC 6629

Mag 11.3

Size 16" by 14"

by Jack B. Marling



NGC 6445

Mag 11.0

Size 38" by 29"

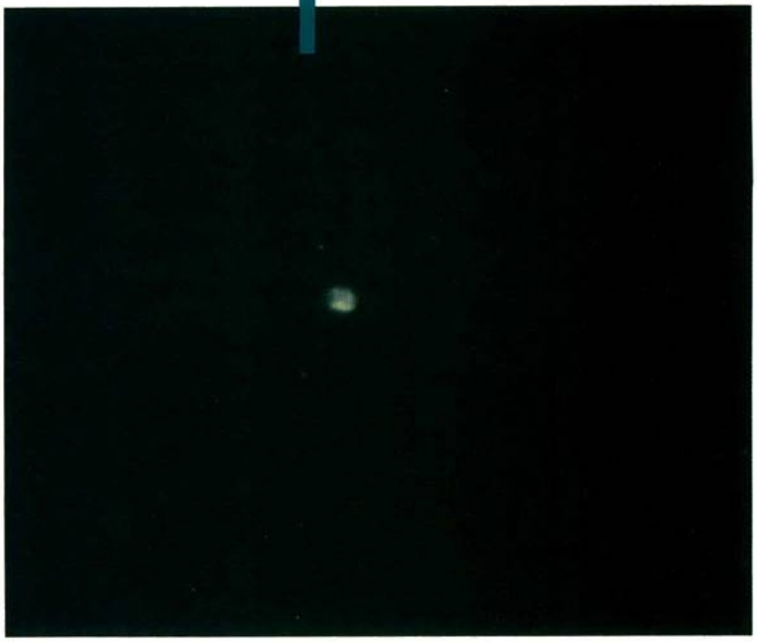
by Jack B. Marling

NGC 6818

Mag 9.3

Size 22" by 15"

by Martin C. Germano



NGC 6440

Mag 9.3

Size 5.4'

by Jack B. Marling

NGC 6567

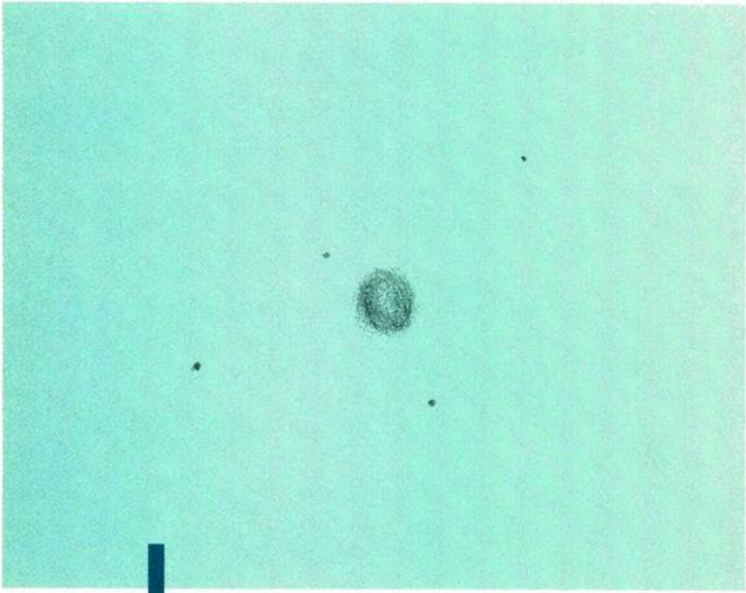
Mag 11.0

Size 11" by 7"

by Martin C. Germano

BRIGHT PLANETARIES IN SAGITTARIUS

Planetary	R.A. (2000.0) Dec.		Mag.	Mag.*	Size
NGC 6445	17h49.3m	–20°01'	11.0	19.0	38" by 29"
NGC 6537	18h05.1m	–19°51'	11.6	—	10" by 9"
NGC 6565	18h11.9m	–28°11'	11.6	15.9	10" by 8"
NGC 6563	18h12.0m	–33°52'	11.0	15.4	54" by 41"
NGC 6567	18h13.8m	–19°05'	11.0	14.4	11" by 7"
NGC 6578	18h16.3m	–20°27'	12.9	15.7	9"
NGC 6629	18h25.7m	–23°12'	11.3	12.8	16" by 14"
NGC 6644	18h32.6m	–25°07'	10.7	15.6	3"
IC 4732	18h33.9m	–22°36'	12.1	16.9	3"
IC 4776	18h45.8m	–33°21'	10.8	14.5	8" by 6"
NGC 6818	19h44.0m	–14°09'	9.3	14.9	22" by 15"



NGC 6818

13.1-inch f/4.5 reflector

269x

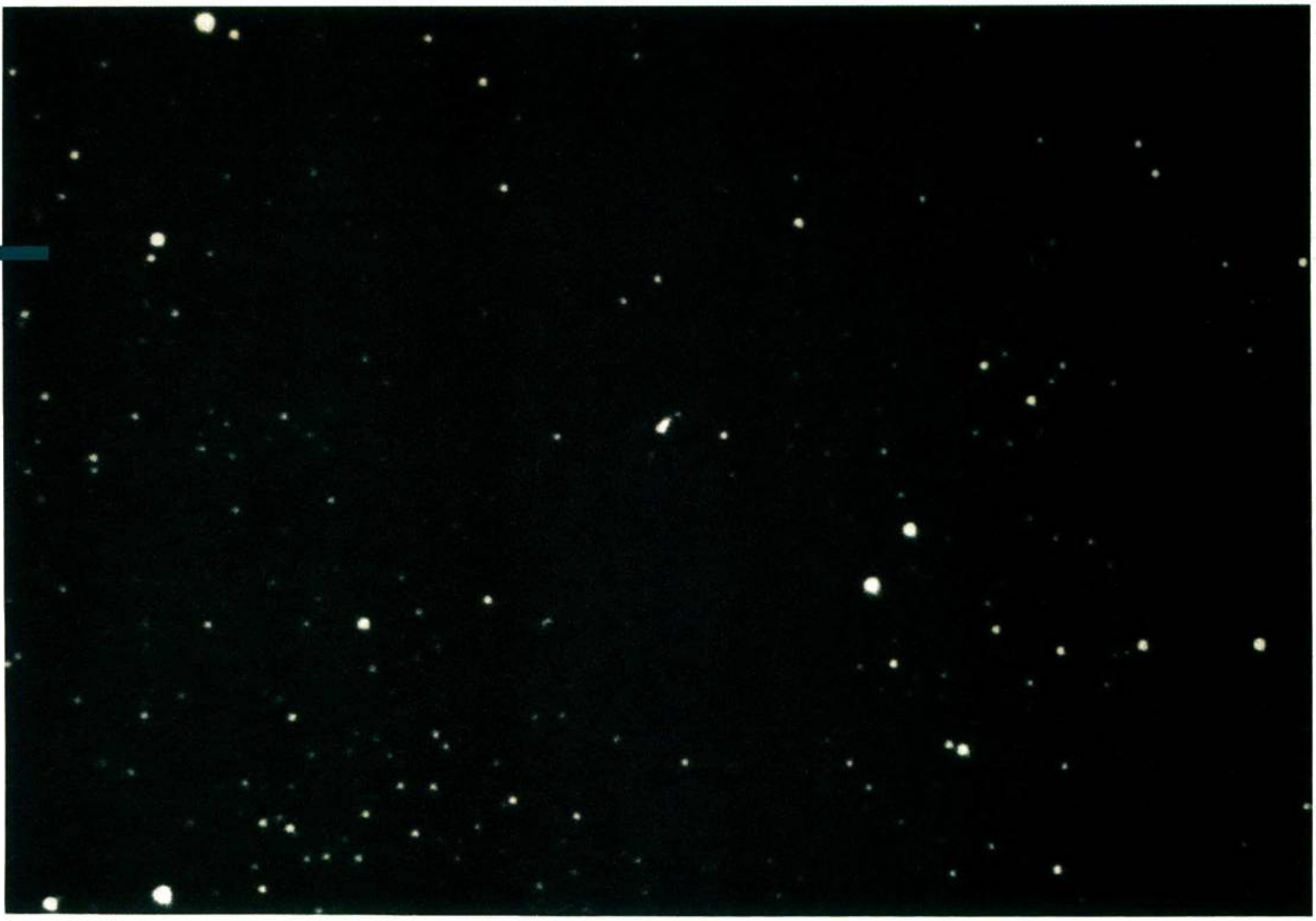
by Richard W. Jakiel

NGC 6818

Mag 9.3

Size 22" by 15"

by Jack B.Marling



bright star Lambda Sagittarii, you'll find several more nebulae. Several globular clusters lie in this region, the most prominent being M22 and M28. Our first stop is **NGC 6644**, a tiny, bright planetary only 1° east and 15' north of Lambda. The small 9th-magnitude globular cluster NGC 6638 shares the same low-power field with the nebula. NGC 6644 glows at magnitude 10.7, but its disk appears nearly stellar. A mere 3" across, the planetary resembles a small, distant planet. The planetary **NGC 6629** lies about 1.8° north of the globular cluster M28. Visually, the 11.3-magnitude disk is an ellipse measuring 16" by 14", or about the same size as Saturn's globe. The central star glows at magnitude 12.8 and is easily visible in most backyard scopes.

A little over 1° north and 20' west of the giant globular M22 is the tiny nebula **IC 4732**. Glowing at 12.1 magnitude, the diminutive disk is only about 3" across, making it a good test of your observing skills. In the same field lies a faint nebula, **PK 10-6.2**, which is a difficult object even for large scopes, glowing feebly at magnitude 14.7. Sweeping over 10° south is a bright, isolated nebula designated **IC 4776**. This object resides in a rather barren section of Sagittarius about 1° southeast of the globular M70. It is one of the brightest planetaries in this part of the sky, shining respectably at magnitude 10.8. In comparison, M76, the Little Dumbbell Nebula in Perseus, is only slightly brighter. IC 4776's evenly lit disk measures 8" by 6", but the nebula's high surface brightness aids in identification.

NGC 6818 is one of the finest planetaries of the southern sky. The most striking property of this nebula in a small telescope is its color, emerald green. In large scopes NGC 6818 takes on a more bluish hue. To find this gem, star-hop your way to 54 Sagittarii and sweep 1° east and 2° north along a short chain of 5th- and 6th-magnitude stars. NGC 6818 is a ring nebula similar to M57 except it is only one-quarter the size, or about 22" by 15" across. With a magnitude of 9.3, it rivals the more famous M57 in total brightness and has a much higher surface brightness. The inner portion of this ring nebula is not as dark as that in M57, but it is distinct in most scopes. The 15th-magnitude central star is a pretty tough customer in most scopes, providing a worthy test object for a 12-inch telescope.

The little-known planetaries of Sagittarius offer a nice contrast to the showpiece features of the constellation — the Lagoon and Trifid nebulae, M22 and M28, and the Small Sagittarius star cloud. Several of these nebulae are bright enough to observe with small scopes, although a few will challenge owners of large backyard instruments. Take time this summer to explore the world of planetary nebulae scattered along the backbone of the Galaxy, and you'll be glad to have added a new dimension to summertime observing. ☐

Richard W. Jakiel is a graduate student in Atlanta and a frequent contributor to ASTRONOMY. He is a contributor to Stars and Galaxies, ASTRONOMY's Guide to Observing the Cosmos *(AstroMedia, 1992).*

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ASTROPHOTO OF THE MONTH

NGC 6334 in Scorpius. Photo by Chuck Vaughn using a 300mm f/4.5 telephoto and LUMICON H-alpha Pass Filter, 30 minutes exposure using LUMICON hypered 2415 film. This nebula is seen best visually with either a LUMICON UHC or Oxygen-III filter.

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BUY 2, GET 1 FREE!!

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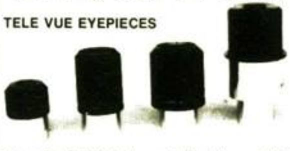

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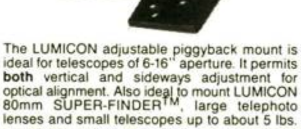

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Celestron C-14, f/11 Schmidt-Cassegrain telescope system. The Celestron C-14 is the ultimate in compact large aperture telescopes. It is ideal for all serious viewing and astrophtography.

SALE ENDS JUNE 30, 1992

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ASTRONOMY February 1991

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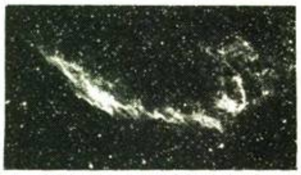
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



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Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings.I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

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U.S. Patent 4,473,636

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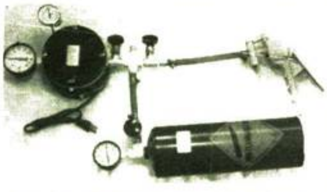

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Full aperture. Installs in seconds. Specify 2" or 1¼".

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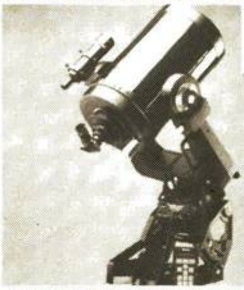
8" LX200

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LX200 Drive, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object.

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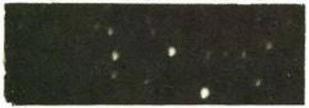
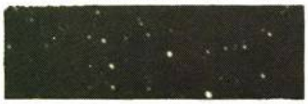
Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



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1.8x Multiplier Lens (2" Barlow)

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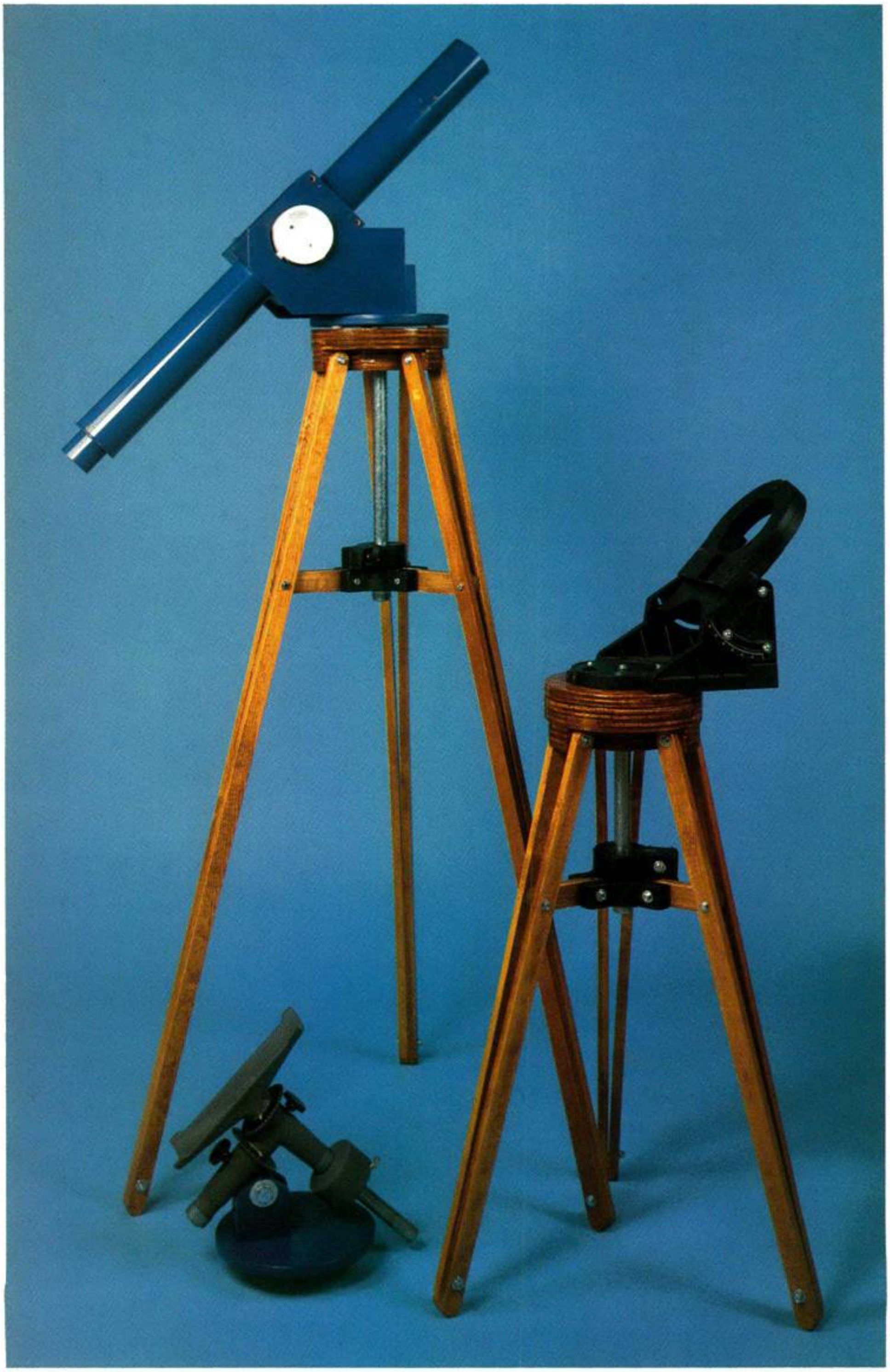
BUILD A UNIVERSAL TRIPOD



ASTRONOMY: All photos by Darla Gawelski except as noted.

Use this versatile, sturdy tripod with your binoculars, reflectors, or refractors.

by M. Leon Knott

A lightweight, all-purpose tripod solved my observing problems. I can use my 8-inch Schmidt-Cassegrain on its wedge for solar viewing during the day and switch to my 6-inch f/5 Dobsonian for nighttime observing using the same sturdy tripod. Another simple switch and I'm using binoculars or a 6-inch Newtonian reflector. The tripod can support Dobsonian, cantilevered Dobsonian, German equatorial, and Schmidt-Cassegrain wedge mountings. It also doubles as an observing stool. (Ouch! Remove the Teflon pads and central bolts first.) All of this strength and capability can be yours for about $40.

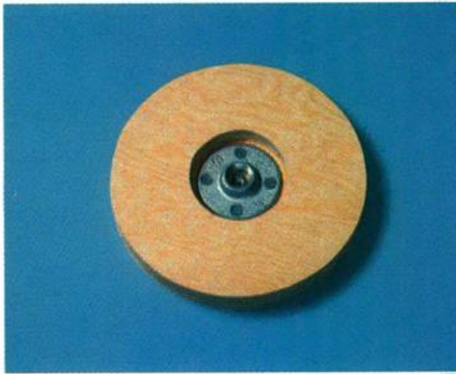
The secret of this tripod's success is simple. The legs have triangular cross-sections, giving them incredible lateral stability. The wooden components dampen out vibrations caused by moving the scope or bumping into the mount. The tripod folds for storage and easy transport. Large bolts at the moving joints allow tightening for future wear and provide the friction for rock-solid structural support.

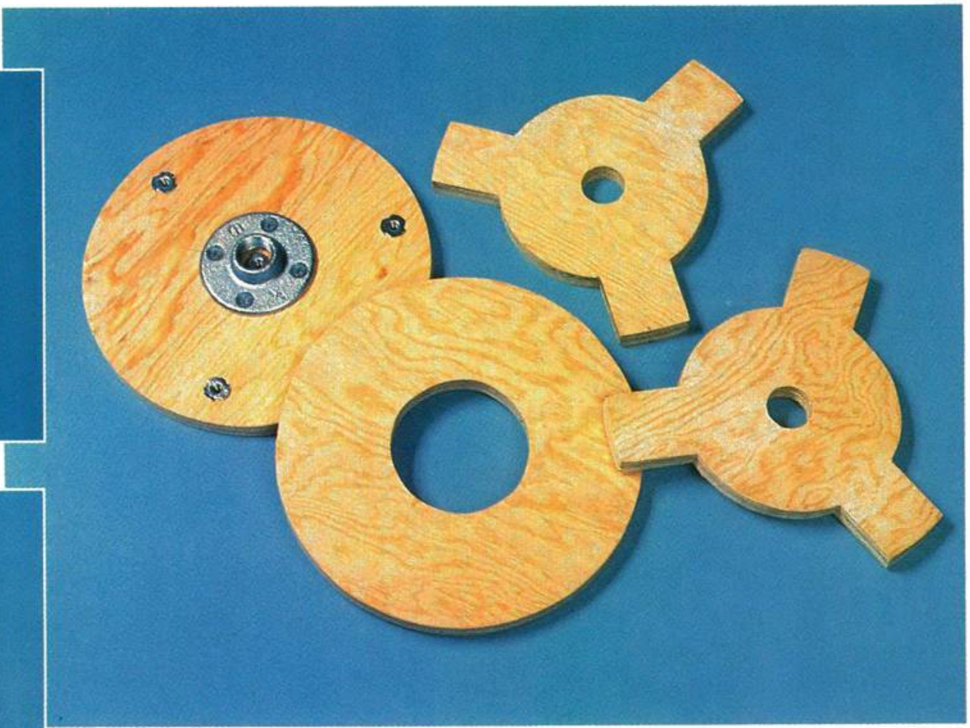
The tripod contains three basic assemblies: the tripod head, the legs, and the spreaders. The tripod head holds the scope mount and secures the tops of the tripod legs. The spreaders prevent the legs from extending too far and also tie the legs together for rigidity.

The Tripod Head

Building the tripod takes a week-

THIS EASY-TO-BUILD TRIPOD *handles Dobsonian rocker boxes, German equatorial mounts, and Schmidt-Cassegrain wedges with ease.*





BUILD THE TRIPOD HEAD from four 3/4" plywood pieces. A pipe flange ties the legs together and mounts on the bottom of the top disk. T-nuts attach the scope mounts to the tripod. Glue and screws hold the four pieces together.

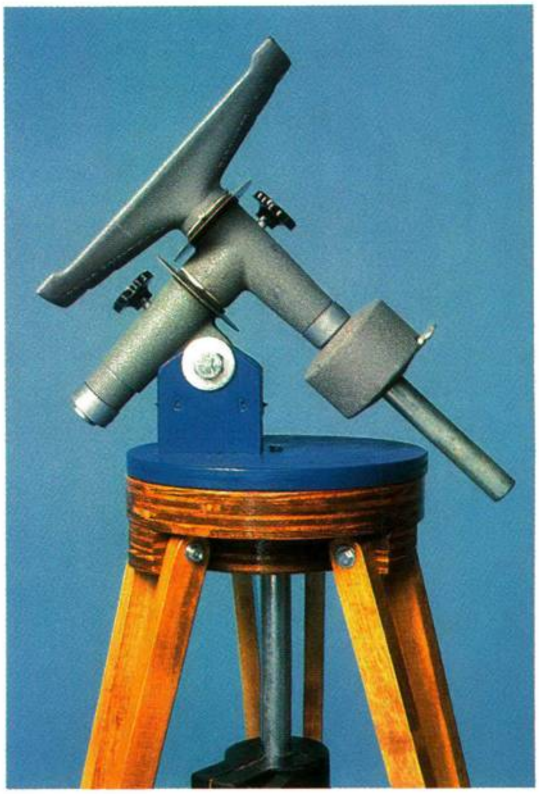
end or two. Let's start with the tripod head. I built my head assembly from 3/4" exterior grade (A-C) plywood. (Depending on the finish you want to apply to the tripod, you may wish to use a more expensive cabinet-grade plywood. You could also use hardwoods for the tripod head.) A quarter panel (2' by 4') is more than sufficient for all of the tripod parts.

The tripod head contains four pieces of wood: two 10"-diameter disks and two hubs. (You may wish to make the disks larger for big scopes.) Cut a 3 1/2" circle (or a little wider than the 3/4" pipe flange) in the center of one of the disks. This becomes the bottom disk. The hubs have a triangular shape (see photos above) with an outer diameter of 10". A template makes transferring the hub design to the plywood sheet easier. The arms of the hub are 2" wide and the inner circular section of the hub has a diameter of 7". Mark the center of the hubs for a hole to be drilled later. Cut the disks and hubs from the sheet of plywood with a power scroll saw. Consider buying a "laminate" blade that cuts on the down stroke of the saw to make smooth, curved cuts.

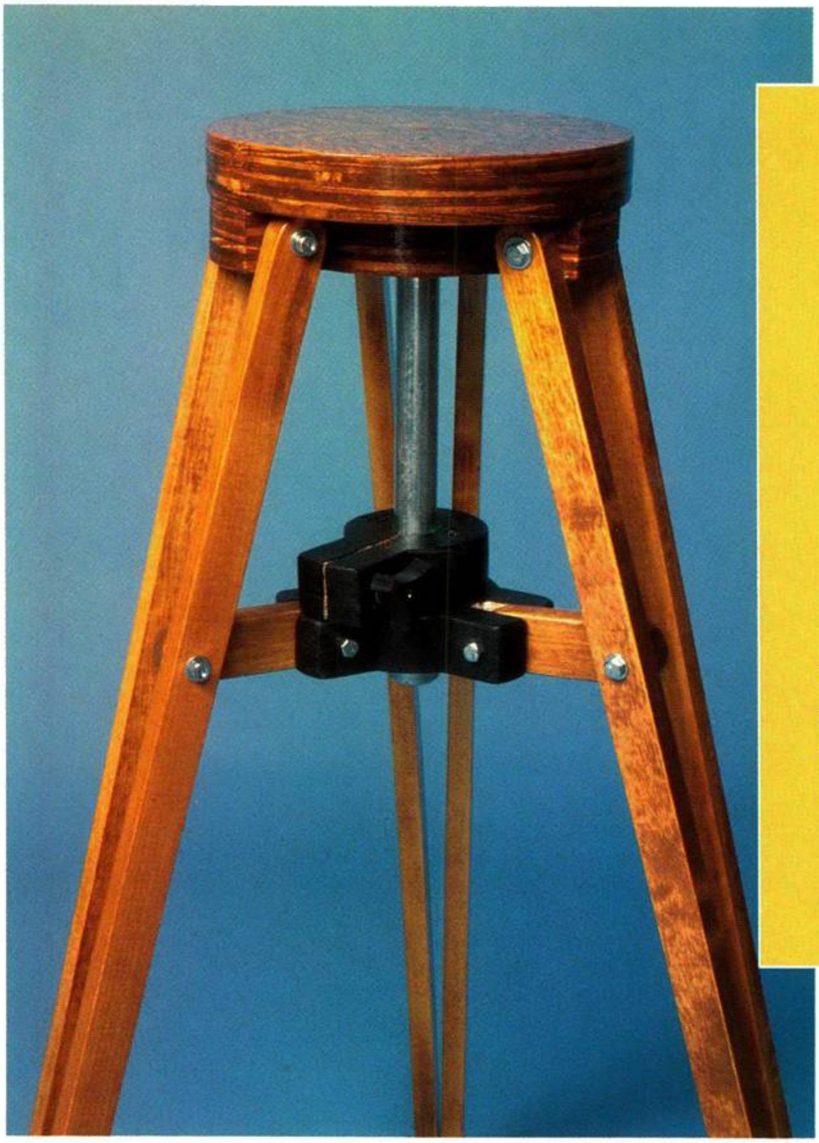
On the top disk, lay out the positions for the mounting holes required for your telescope mounts. T-nuts fit into these holes to secure the mounts. My tripod has T-nuts for an 8" Schmidt-Cassegrain wedge, two Dobsonian rocker-box mounts, my mirror-plus-binocular observing system, and a flange that holds a German equatorial mount. The T-nut holes used for my wedge double as the holes for the Dobsonian Teflon bearings. I simply screw 1/4-20 bolts through three countersunk Teflon pads. A center T-nut and bolt hold the rocker box in place on the tripod head.

Drill holes through the disk at the mounting hole positions and install 1/4-20 T-nuts in the holes. (My T-nuts required 5/16" holes.) Make sure the bottoms of the T-nuts are flush with the surface of the wood. The T-nuts will actually be sandwiched between the plywood disks and provide strong mounting points. On the bottom side of the disk, center the pipe flange and fasten it with 1/2" screws.

Fasten the two disks together with carpenter's glue and 1 1/4" screws. Likewise, join the two hub pieces together. Once the glue is dry, drill a 1 1/4" hole in the center of the hub. Drill the hole halfway from each side for a truer hole and to avoid splintering the wood at the surface. Shape the hubs — except for the outer edge (10" diameter) — with a rasp and



THE LEGS ATTACH to the tripod head with 4" bolts. Tighten these bolts to prevent twisting or lateral motion of the tripod.



THE SLIDING HUB TIES THE LEGS to the pipe and locks them in a triangular shape for rigidity. The block locks the hub in place when the tripod is set up.

TRIPOD PARTS LIST

1	2' x 4' section of 3/4" plywood
3	3/4" x 1 1/2" x 96" clear pine (for legs up to 45" long)
1	3/4" pipe flange
1	12" to 18" length of 3/4" pipe
1	3/4" pipe cap
1	1/4-20 threaded knob
	1/4-20 T-nuts
3	1/4-20 x 4" screws or carriage bolts
7	1/4-20 x 3" screws or carriage bolts
3	1/4-20 x 2" screws or carriage bolts
12	1/4-20 nuts
26	1/4" washers
13	1/4" lock washers
10	1 1/4" wood screws
3	2 1/2" wood screws
	carpenter's glue
	stain and varnish or paint

then sand them. Also sand the bottom portion of the joined disks.

The bolts for leg attachment require holes in each arm of the hub. Drill the hole about 1" from the outer edge and along the central gluing face. As with the central hole, drill halfway from each side for a truer hole.

Align the central hole in the hub with the pipe flange in the disks. Glue and fasten the hubs to the disks with 2 1/2" screws. The finished tripod head consists of four layers of plywood. When the glue has dried, shape the outer edges of the disks and hubs with a rasp.

Legs and Supports

Two pieces make up each leg. Their length depends upon your scope (or scopes), the type of mount, and your height. A refractor might need legs as long as 60" to permit easy viewing near the horizon, while a reflector might require 30" to 36" legs to permit comfortable viewing near the zenith. Make the legs a little longer than you estimate you'll need because you can cut them shorter but not easily make them longer.

Round the ends of the legs to prevent chipping and splintering of the wood. A bolt through a hole about 1" from the bottom end joins the legs. A second hole about 11" from the top (16 1/2" for long legs) will hold the spreader bolt. This hole should position the spreader at the bottom of the pipe. A hole about 5/8" from the top will pass the bolt connecting the legs to the tripod head.

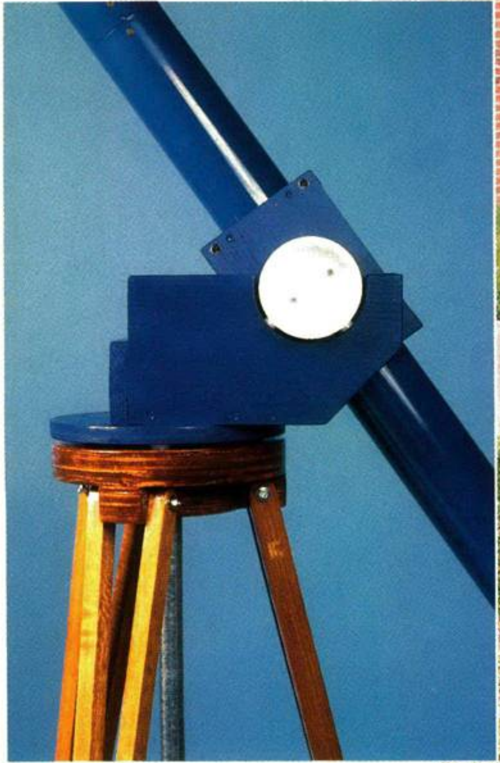
The pipe mounted to the tripod head forms the central support for the legs (see photo above). A 7" plywood hub moves up and down the pipe. Spreaders connect the sliding hub to the legs, thus locking the legs into a triangular section.

The sliding hub has a similar shape to the hub in the tripod head assembly. The major difference is that the sliding hub has a 3/4" slot cut in each arm to hold a spreader. To prevent the wood from splitting, the total width of each arm should be at least 2 1/2".

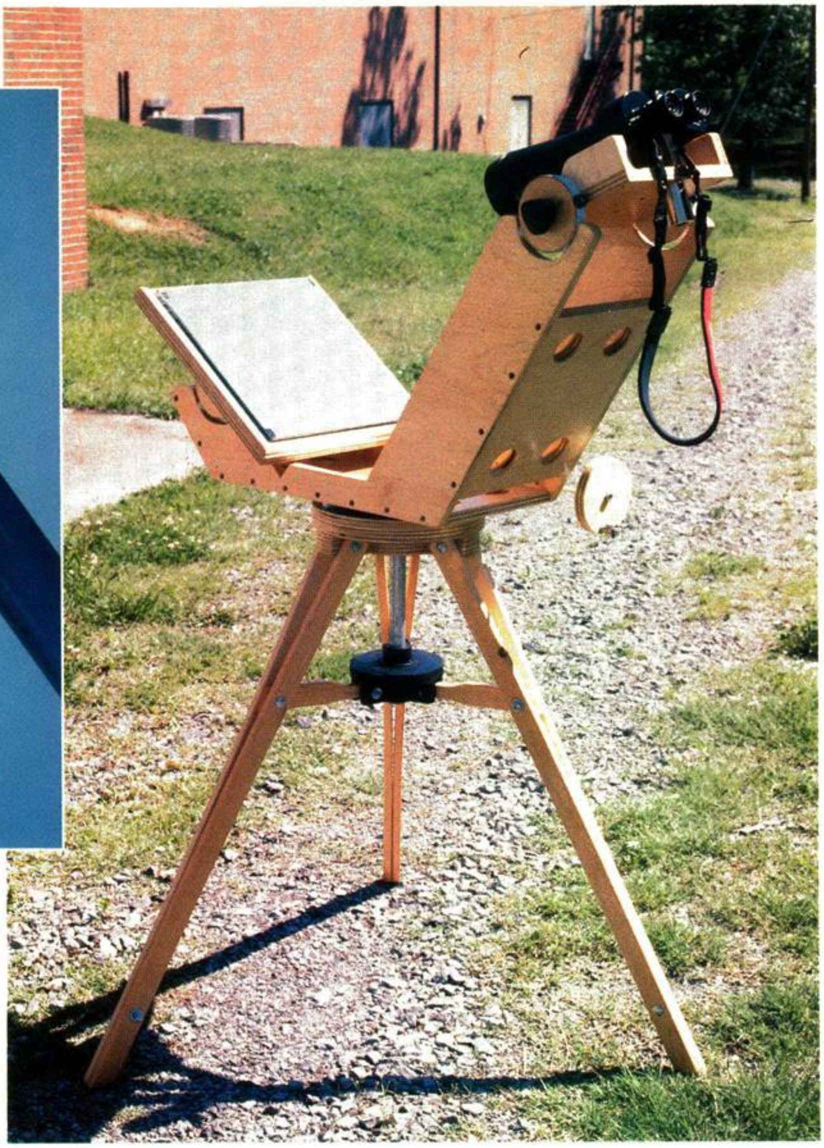
Cut the two pieces of the hub from 3/4" plywood. A template facilitates laying out the design on the plywood. If you use A-C plywood and put the good side of the wood out, turn the template over to lay out the second hub piece to reduce any chance of error when joining the two pieces. Glue and screw the pieces together with two 1 1/4" screws in the central portion of the hub. Once the glue has dried, shape the pieces with a rasp. Be sure that the spreaders will fit in the slots.

Drill a 1 1/8" hole in the center of the sliding hub, again drilling halfway from each side. The pipe should slide freely through this hole but not wobble in the hole.

Drill holes for 1/4" bolts in the arms of the sliding hub about 1" from the end and along the central glue joint. Place a scrap block of wood in the slot to prevent the drill from splintering the wood of the arm.



A ROCKER BOX PROVIDES an altazimuth mount for small refractors and reflectors. The box uses nylon or teflon pads for bearings.



M. Leon Knott

A MIRROR TURNS the gaze of these binoculars upward, preventing neck strain. Use a front surface mirror to avoid annoying ghost images.

A separate block locks the sliding hub in place (see photo opposite). It consists of two 3/4" plywood pieces glued and screwed together. The block is a 3 1/2" circle with an arm that extends another 1 3/4". The block has a 1" central hole and a 1/8"-wide slot cut through the arm to the central hole. Drill a hole 1" from the end of the arm along the glue seam. A 1/4" bolt and a T-handle clamp the block in place on the pipe when the tripod is set up. You may wish to screw the clamping block to the sliding hub after you test fit them on the pipe.

The spreaders fit between the sliding hub and the legs. The exact length depends on your tripod height. The bottoms of the legs should extend beyond the head of the tripod 1" for every 5" to 7" of tripod height. Spreaders will thus be about 5" to 6 1/2" long. Place the bolt holes in the spreaders 3/4" from the end to prevent splitting. Round the ends of the spreaders so they will pivot in the hub and legs more easily.

Finish and Assembly

Sand all the pieces to remove splinters. You may wish to sand further to provide a smoother finish. The tripod will last longer if it is finished, so stain and varnish or paint it according to your taste. If you are painting the tripod with an enamel or other finish that bonds to itself upon contact, you may not want to paint the portions of the tripod head, sliding hubs, and legs where they meet.

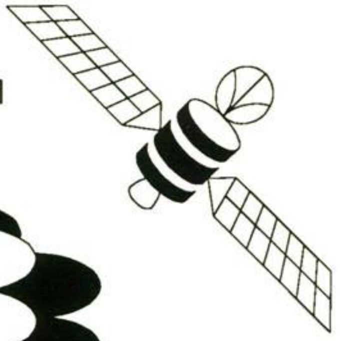
After the finish is dry, the pipe may be screwed into the flange in the tripod head. Insert but do not tighten 2" bolts in the bottoms of the legs. With the tripod head on the ground, attach the legs to the tripod head with 4" bolts. Slide the locking block and then the sliding hub over the pipe and screw on the pipe cap. Attach the spreaders to each leg and the sliding block with 3" bolts. Now tighten the bolts on the bottoms of the legs.

Invert the tripod so it is standing. Tighten the leg bolts just enough to provide a strong friction fit — too tight and the tripod will not fold, too loose and the legs will allow too much twist or lateral motion. Trial and error will lead to the proper bolt tension. Folding and unfolding the tripod is a matter of simply unlocking and locking the block and moving the sliding hub up and down the pipe.

The universal tripod is portable yet sturdy. Replacing the tripod's short legs with longer legs will transform the tripod from a reflector mount to one for refractors. This tripod could be your solution for that unmounted scope in the garage or for those observing sessions in the country when you want a lightweight tripod. Its uses will stretch as far as your imagination. ☐

M. Leon Knott has built telescopes for 15 years and operates StarStorm, a telescope-making company in Flagstaff, Arizona.

STARGAZE Version 2.1



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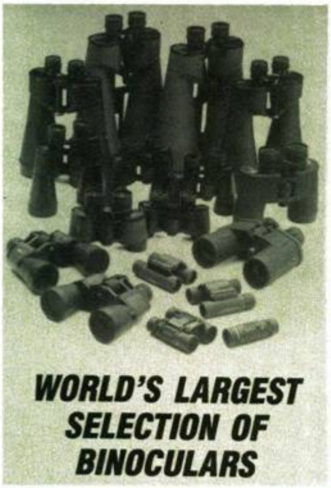

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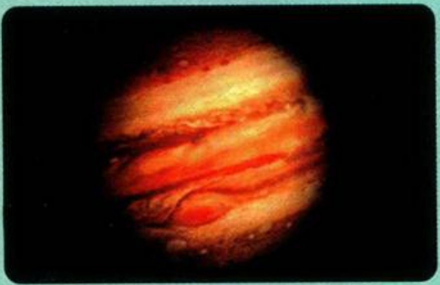

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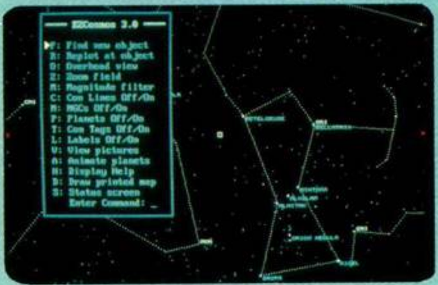
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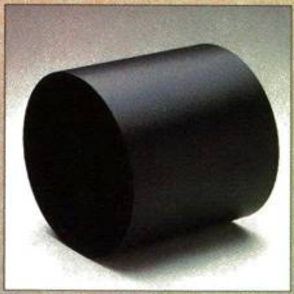

LENS SHADES—the new 11" lens shade is made of aluminum for long life and to complement the appearance of the C-11 telescope. It offers higher contrast views and helps eliminate dewing.

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WATCHING THE DAYTIME STAR

Astronomy happens at *night*, right? Well, lots of it does — but not all of it. Daytime astronomy, *a.k.a.* solar observing, offers an easy way to get into the hobby and to learn the whys and wherefores of using a telescope. Observing the star that powers our solar system is downright dangerous, however, unless you are careful to use a solar filter properly attached to the front (aperture) end of your telescope. Do not use a filter placed in an eyepiece. This method could lead to instant blindness if an eyepiece filter were to shatter because of extremely high temperature. With a proper front-end filter, however, observing the Sun is safe and provides an amazing, upclose look at the most important star in our lives.

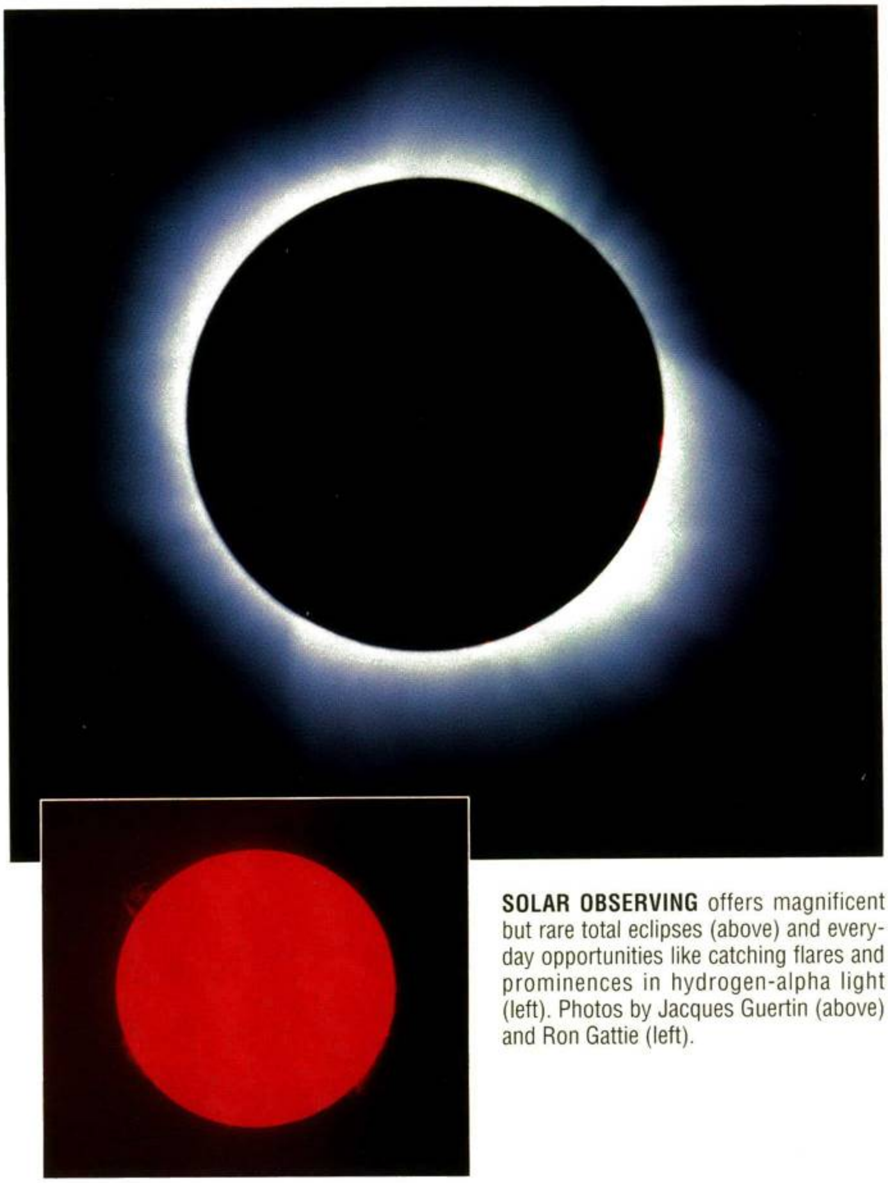
Getting to Know You. "Observing the Sun wasn't my cup of tea when I became interested in astronomy," recalls Brenda Culbertson of Topeka, Kansas. "My idea of backyard observing was picking off faint fuzzies at the eyepiece of my telescope under a dark, night sky." Over the past few months, however, Culbertson has found herself increasingly attracted to daytime observing. "One day I thought, if I get too cold during the night, why not observe during the day? Not only would I be warm and comfortable, but I wouldn't have to drive a long way to reach some remote dark sky site."

Getting to know the Sun transformed Culbertson's notions about observing and amateur astronomy overall. "I picked up the filter I had used to photograph the 1991 total eclipse, placed it on my telescope, and began to watch the Sun's surface for a short period every day," says Culbertson. "At first I was quite surprised to find its face speckled with sunspots. Now I've graduated to photographing the Sun regularly and can feed the images to my VCR for playback at my leisure. I'm glad I tried daytime observing. I won't give up nighttime astronomy but watching the Sun added another element to my enjoyment of amateur astronomy."

Sunset Heaven. "It was more than just another sunset," remarks Chris Baldock, a member of the Royal Astronomical Society of Canada's London Centre. "Last February an observing friend and I were outside wondering aloud about packing away our parkas and wishing for warm weather. This conversation jogged my memory about an observing experience I had the previous July.

"It was a hot day on the beach along beautiful Lake Huron. The beachfront was crammed, most of us annoyed at the blazing heat of the Sun. Little did we realize that later in the day the ball of fire would provide us with a spectacular sight."

As the Sun slowly sank in the west, Baldock explains, it formed a dazzling illusion because of currents of hot and cool air on the horizon. "Old Sol underwent a strange metamorphosis," recalls Baldock, "bending, distorting, reflecting, refracting, until it was no longer our familiar daytime disk but a zoo of unusual shapes. The imaginations of the onlookers were unleashed as the remaining light from the Sun twisted into weird forms. Someone called it a mushroom. Another person nearby said it was a stack of random geometric shapes. Someone else likened it to a fire hydrant. Then came a light bulb, a stained-glass window, an exhaust plume, a luminous egg, and a salt shaker. It slowly oozed into the lake, but not before leaving the beachfront audience breathless." Isn't the Sun wonderful? How else could a day at the beach turn into a magical show in the sky? — *David J. Eicher*



SOLAR OBSERVING offers magnificent but rare total eclipses (above) and everyday opportunities like catching flares and prominences in hydrogen-alpha light (left). Photos by Jacques Guertin (above) and Ron Gattie (left).

THE WONDERS OF THE DEEP SKY

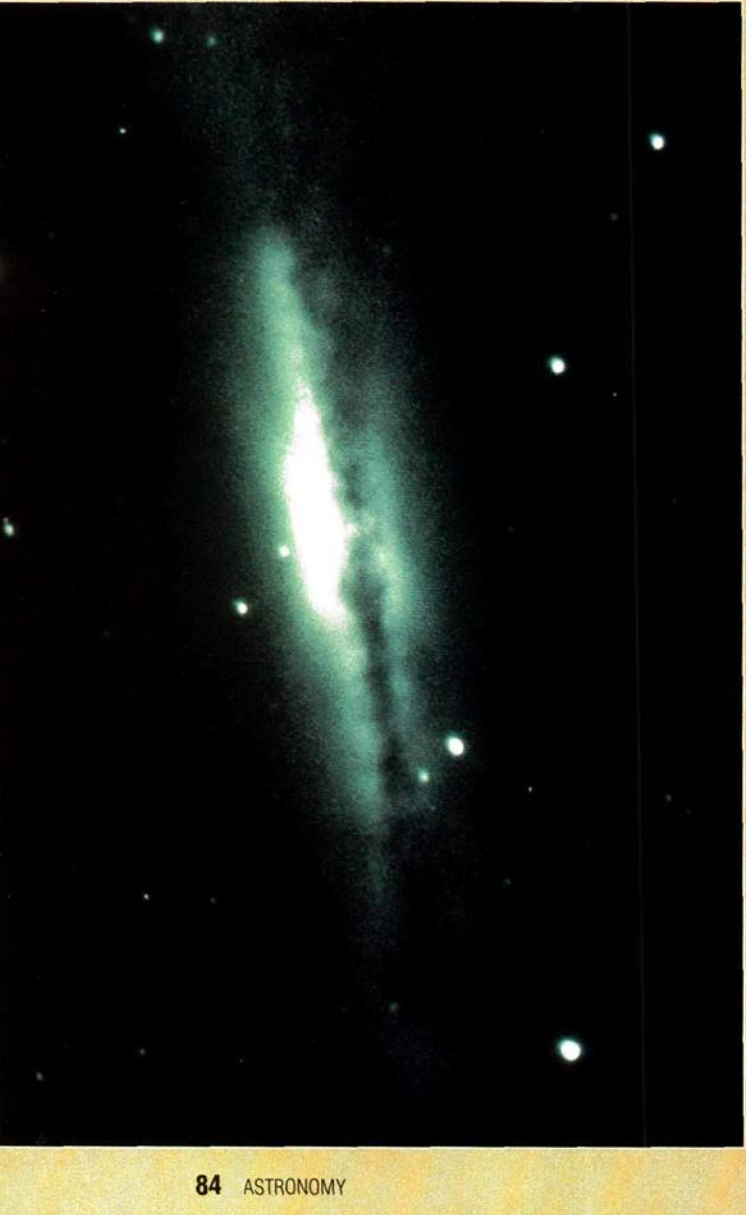
The Rosette Nebula is a huge wreath-shaped cloud of warm hydrogen gas in the constellation Monoceros. Its splendor as a winter target for astrophotographers is hardly surpassed, yet it is a difficult object for visual observers because of low surface brightness. Bill and Sally Fletcher's photo of the emission nebula (opposite page) captures this month's $100 "Best Astrophoto" award. The Fletchers used an 8-inch f/4.5 reflector, Fujichrome 400 film, and a 70-minute exposure.

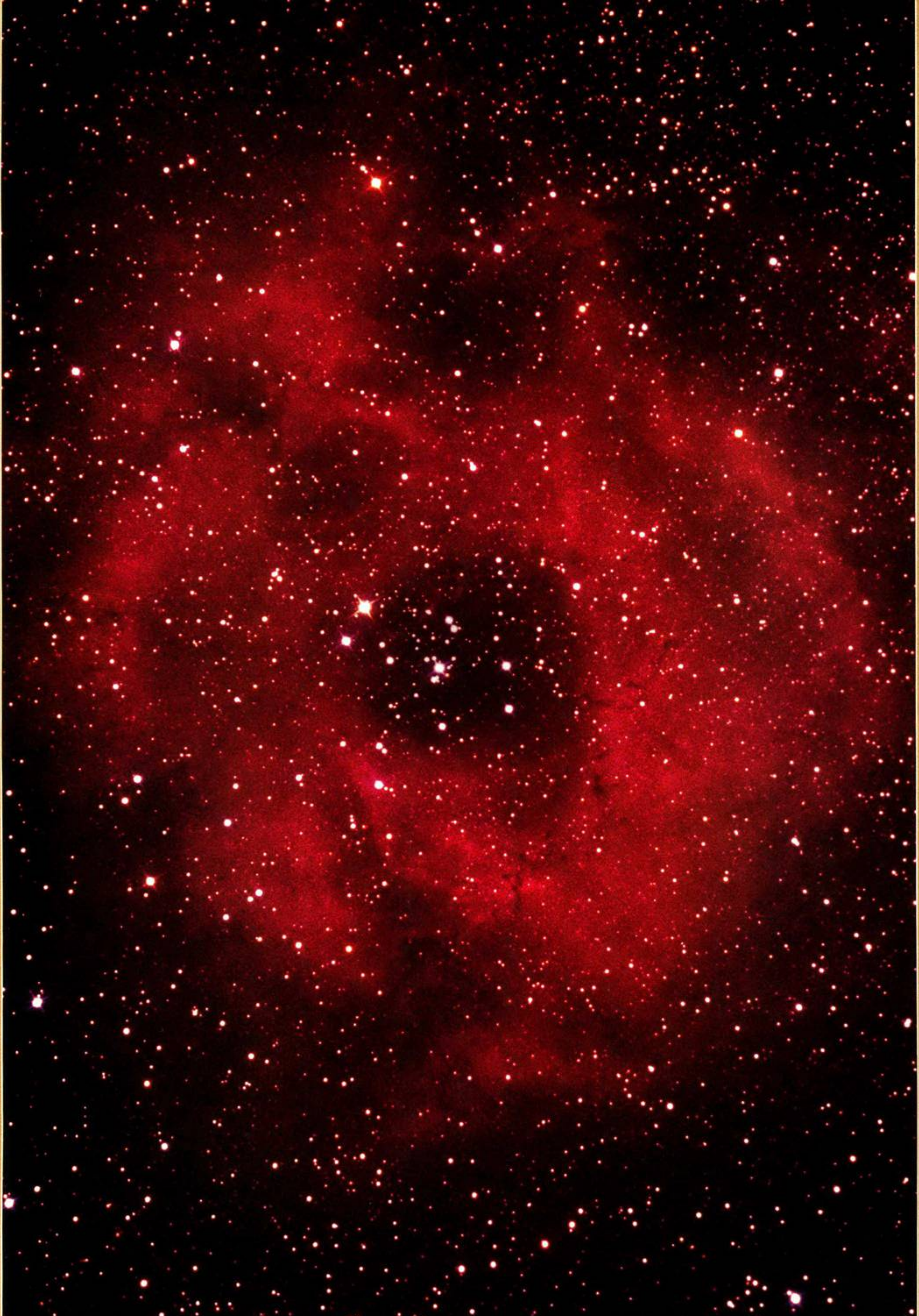
The southern sky holds an emission nebula so bright it is visible to the naked eye — the Eta Carinae Nebula. Bill Sterne's photo of stars trailing about the South Celestial Pole (below) reveals light from Eta Carinae smeared into a diffuse pink glow.

Another gem of the southern sky is the galaxy NGC 4945 in Centaurus. Australian astrophotographer Steve Quirk shot the galaxy (bottom) with his 10-inch reflector. Sharp-eyed readers can spot two other galaxies, NGC 4945A and NGC 4976, in the same field.

Using a 20-inch Cassegrain telescope and a Photometrics STAR I CCD camera, New York amateur Ronald W. Kohl produced a closeup view of the galaxy NGC 3628 in Leo (below left).

A recent photo made by Las Vegas, Nevada amateur George Greaney shows one of the faintest winter emission nebulae, IC 2118 in Eridanus (left). Nicknamed the Witch Head Nebula, IC 2118 has such a low surface brightness that it is within reach of only the largest telescopes.





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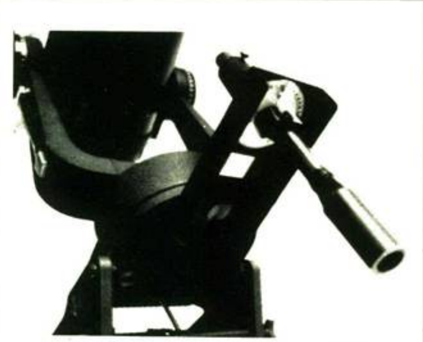

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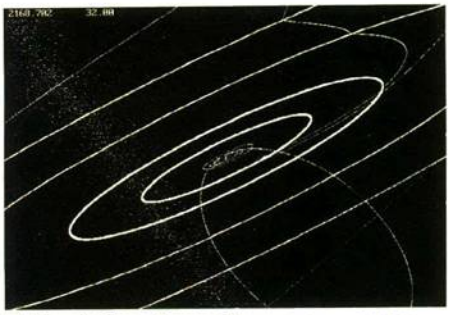

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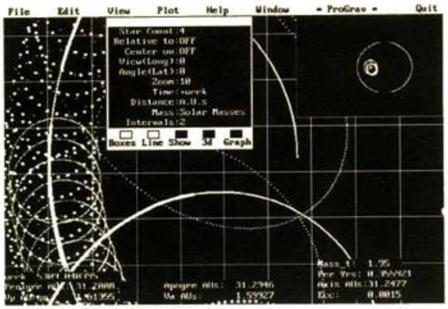

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Relative to:OFF
Center on:OFF
View(Long):0
Angle(Lat):0
Zoom:10
Distance:A.U.s
Mass:Solar Masses
Intervals:2

Apogee Abs: 31.2946
Va Abs: 1.59927
Mass_t: 1.95
Axis Abs:31.2477
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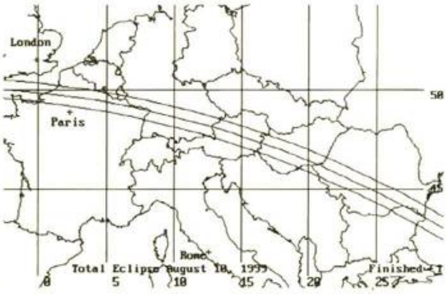

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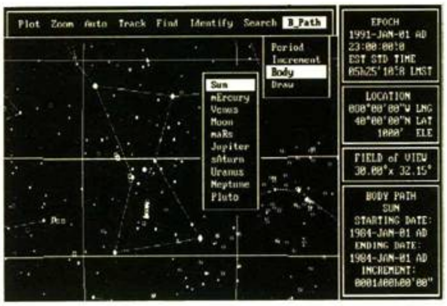

EPOCH
1991-JAN-01 AD
23:00:00.0
EST STD TIME
05h25'10.8 LMST

LOCATION
000°00'00"W LNG
40°00'00"N LAT
1000' ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"

Partial Solar Eclipse
Magnitude: 0.170 Obscuration: 0.3%
LAST CONTACT

(*** NGC 3034 Located at TARGET ***)
(CIRCUMPOLAR)
(CIRCUMPOLAR)

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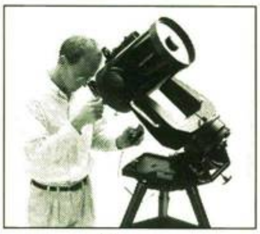

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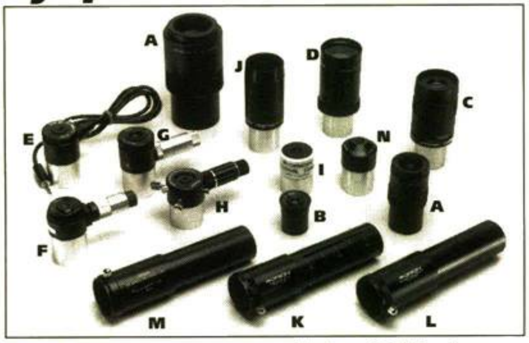

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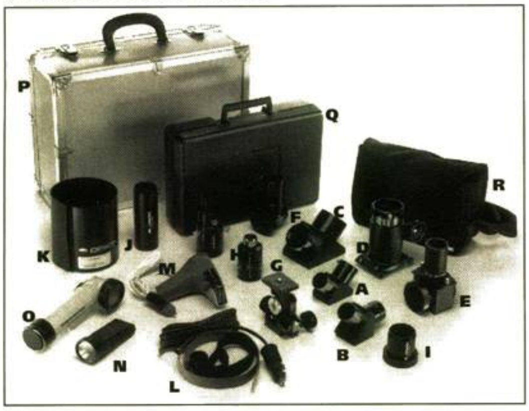

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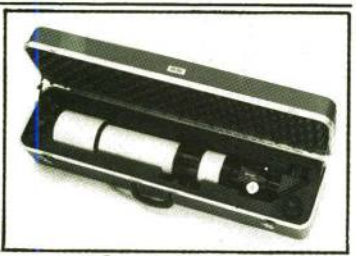

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WHAT'S NEW ON THE BOOK SHELF

Space

Monitoring NASA Communications, by Anthony R. Curtis, (Tiare Publications, 1992), ISBN 0-936653-30-2, 100 pages, softcover, $14.95.

In this book, subtitled *How to Tune in the National Aeronautics and Space Administration on Shortwave, VHF, UHF, and Satellites,* Curtis describes the equipment needed to listen to satellite and space shuttle transmissions. He lists the radio frequencies used for satellite transmissions and shuttle communications and offers a glossary that helps untangle the jargon used by NASA. Curtis also provides a chronology of space missions and a description of some of the satellites found in orbit today.

General Astronomy

A Concise Dictionary of Astronomy, Jacqueline Mitton, (Oxford University Press, 1991), ISBN 0-19-853967-3, 423 pages, hardcover, $24.95.

This dictionary contains over 2,400 entries that describe astronomical objects and terms, including many acronyms and abbreviations. It also includes tables listing bright stars and planetary physical characteristics.

Astrophysics

The New Cosmos, fourth edition, by A. Unsöld and B. Baschek, (Springer-Verlag, 1991), ISBN 0-387-52593-9, 438 pages, acid-free paper, sewn binding, hardcover, $59.

The authors have updated portions of this classic text on astronomy and astrophysics, retaining a mathematical approach (including calculus). The chapters on the solar system, astronomical instruments, stellar evolution, galaxies, active galactic nuclei, and cosmology describe some of the changes in these research areas since the 1983 third English edition. Unlike the last edition, in which the updated information appeared in a separate section, this edition integrates the material into the text. A further improvement is the adoption of the International System of Units (SI).

Astrophysical Techniques, second edition, by C.R. Kitchin, (Adam Hilger, 1991), ISBN 0-7503-0137-6, 496 pages, sewn binding, hardcover, $135; ISBN 0-7503-0138-4, softcover, $45.

This undergraduate textbook on observational techniques has many chapters of interest to amateur astronomers.

The reader can learn how to reduce photometric observations and how astronomers measure X rays and cosmic rays. The book starts with a description of different detectors, including the eye, photographic emulsions, neutrino and gravity-wave detectors, and modern devices such as the charge-coupled device (CCD). Subsequent chapters discuss the use of these detectors and the auxiliary equipment needed for imaging, astrometry, interferometry, photometry, and spectroscopy. Several appendices list the magnitudes of standard stars for use in photometry and standard stars for spectroscopy and polarimetry.

Stars

Variable Star Research: An International Perspective, edited by John R. Percy, Janet Akyüz Mattei, and Christiaan Sterken, (Cambridge University Press, 1992), ISBN 0-521-40469-X, 329 pages, hardcover, $49.95.

These proceedings of the first European meeting of the American Association of Variable Star Observers (AAVSO) describe attempts by amateurs and professionals around the world to measure and understand variable stars. Aimed at advanced amateurs, the book describes major classes of variables and lists possible observing projects. Included in the 38 papers are a discussion of visual search techniques by noted supernova observer Robert Evans, AAVSO programs and visual variable star observing by Janet Mattei, photoelectric photometry by Douglas Hall, the benefits of amateurs' dwarf novae observations by Constanze la Dous, and the need for international cooperation for studies of long-period variable stars.

Solar System

Venus Geology, Geochemistry, and Geophysics, edited by V. L. Barsukov, (University of Arizona Press, 1992), ISBN 0-8165-1222-1, 421 pages, acid-free paper, sewn binding, hardcover, $75.

This collection of general and technical articles reviews the knowledge of our sister planet's geology prior to the Magellan mission. Twenty-two chapters decribe Venus' volcanism, tectonics, impact craters, chemical processes, and interior, and its still puzzling retrograde rotation. The authors highlight data from the Soviet Venera missions, including radar maps from the Venera 15 and 16 missions. An appendix includes over 100 radar images and a second appendix describes hundreds of named features on Venus' surface and how they are named. ☐

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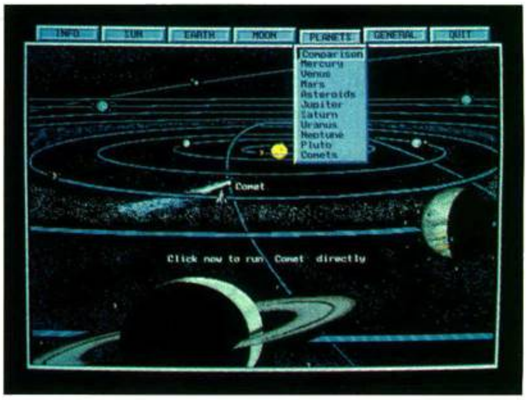
***Orbits: Voyage through the Solar System**, Software Marketing Corporation, 9831 South 51st Street, Building C-113, Phoenix, AZ 85044. Phone (602) 893-2400. $59.95. Minimum requirements: IBM PC-compatible computer, 512 KB memory, DOS 2.0, and EGA graphics. Mouse is optional and 1.5 MB are required if installed on hard disk. Both 5¹/4" and 3¹/2" diskettes are provided.*



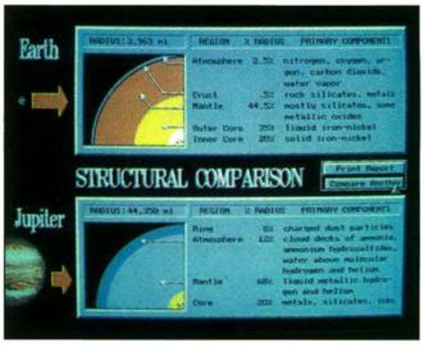
Orbits is an atlas of the solar system. It provides cutaway views of the planets, comparisons of the planets, a satellite orbital simulator, and detailed descriptions of the Sun and planets. The program will appeal to teachers, students, and beginning amateurs who want to learn more about the solar system.

A simple pull-down menu system permits access to all of the program's features. Clicking on a planet's image at the main screen also brings up information about that planet. You can choose between metric and U.S. Customary systems of units. And printouts of side-by-side comparisons of planetary characteristics (as in the photo at right) are only a mouse-click away. For a study break, the program will present a randomly shuffled electronic jigsaw puzzle of a planet's image for you to unscramble (it uses scanned NASA images).

The manual lacks an index, but it is well designed and includes many examples. The text displayed by the program contains some minor factual errors, but it is generally correct and informative. You can operate the program from the keyboard, but a mouse makes it easier.

The satellite orbital simulator provides four "missions" for you to master: near-Earth orbit, deployment of a satellite from a space shuttle, intercepting a satellite with a second satellite, and the rendezvous of a space shuttle with a satellite. As the authors state, these missions provide a good opportunity to learn the basic laws of orbital motion. Unfortunately, the manual provides little guidance about how to accomplish these missions. Some hints in future manual editions regarding one or more of the missions would be helpful.

Orbits is a solid tutorial program that teaches beginning astronomers about the physical nature of our solar system. The menu structure permits users to plan their learning instead of being fed a predetermined lesson plan. I predict that Orbits will become popular as a teaching aid in schools. — *Dave Bruning*



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REGION	% RADIUS	PRIMARY COMPONENTS
Atmosphere	2.5%	nitrogen, oxygen, argon, carbon dioxide, water vapor
Crust	.5%	rock silicates, metals
Mantle	44.5%	mostly silicates, some metallic oxides
Outer Core	[illegible]	liquid iron-nickel
Inner Core	[illegible]	solid iron-nickel

RADIUS: 44,350 mi

REGION	% RADIUS	PRIMARY COMPONENTS
Ring	[illegible]	charged dust particles
Atmosphere	[illegible]	cloud decks of ammonia, ammonium hydrosulfides, water above molecular hydrogen and helium
Mantle	[illegible]	liquid metallic hydrogen and helium
Core	20%	metals, silicates, [illegible]

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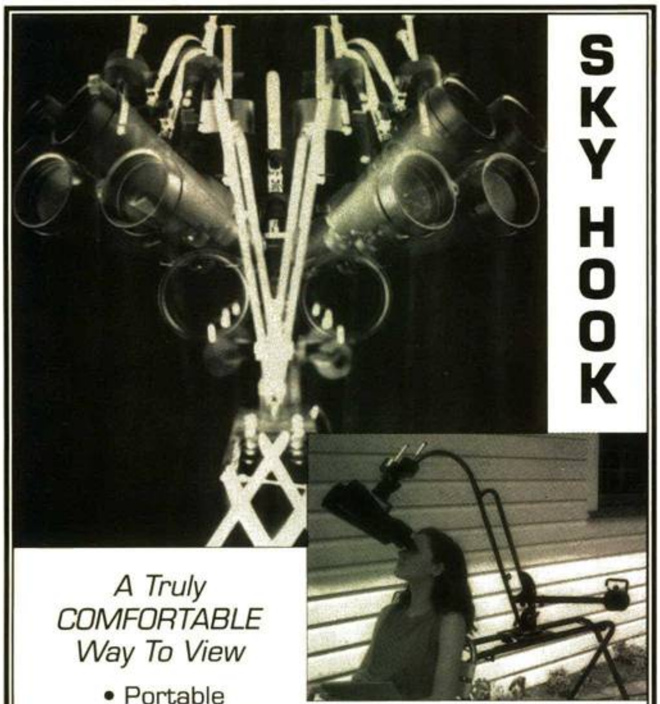

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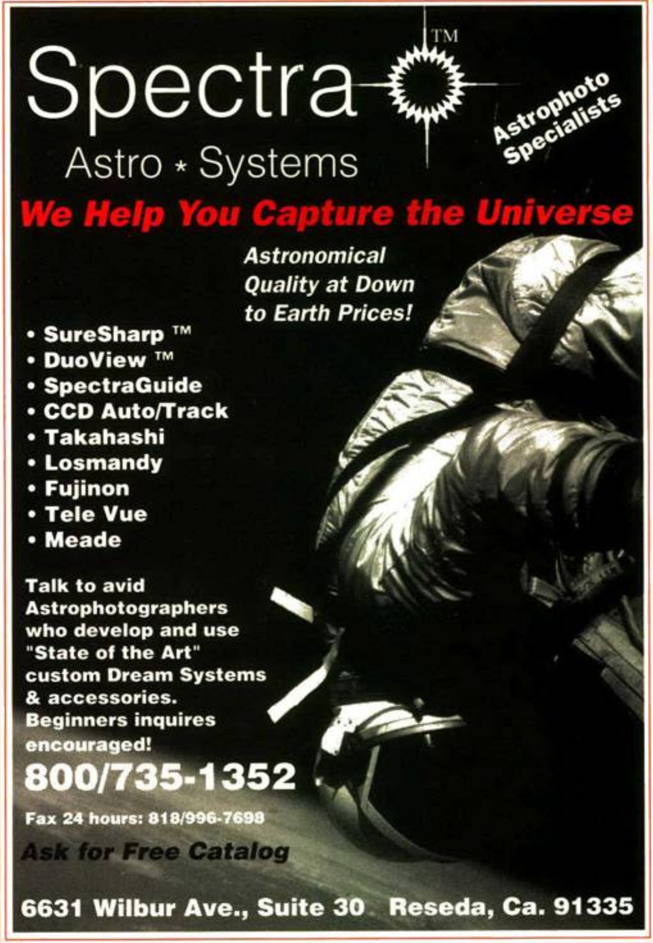

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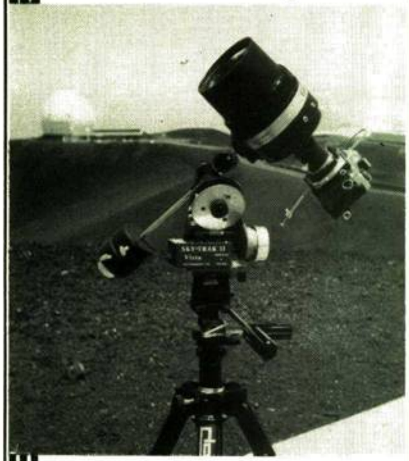

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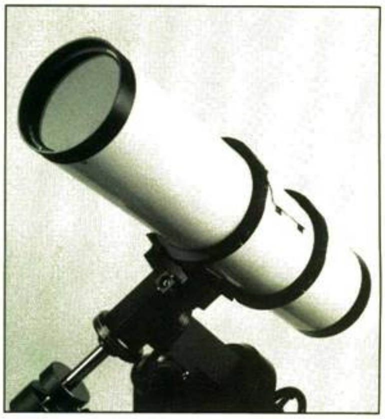
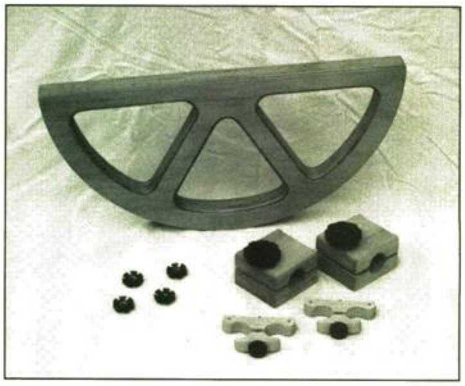


1 Flat Field Camera for Astrophotographers

Offered in Europe for several years, the Flat Field Schmidt-Cassegrain Camera from Lichtenknecker Optics of Belgium is now available in the United States. With a focal length of 760 mm and a focal ratio of f/4, the Flat Field Camera (FFC) projects an image circle 60 mm in diameter with a field of view of 4.5°. Stellar image sizes are stated to be smaller than 10 microns (0.0004 inch) across the spectrum over the entire field, allowing enlargements of the resulting negatives of up to 4 feet across. The FFC can be used with 35mm SLR and 6x7-format camera bodies as well as 4x5 film backs. The camera tube features Invar rods (for focus stability), a curved Schmidt corrector (to eliminate ghost images), and a finely graduated internal focuser. The rear plate is threaded to accept 48mm and 72mm filters. The camera tube is 50 inches long and weighs 35 pounds. It comes with tube rings, dew cap, end covers, Multi-Function focusing device, SLR/visual back, and visual ocular extension. All systems are laser collimated and checked by the distributor.

U.S. Distributor: Jim Riffle, P.O. Box 608B, Cloudcroft, NM 88317. Introductory price: $4,500. Catalog with sample photos $5.



2 Dobsonian Telescope Components

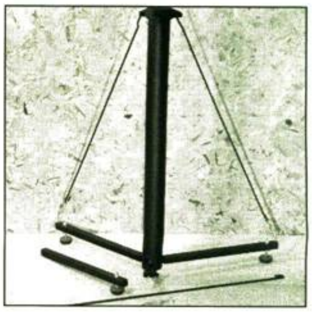
AstroSystems offers side bearings and truss tube clamps for those building their own open-tube Dobsonian telescope. The components are made of aircraft plywood and maple veneer. The half circle side bearings come in 18-, 24-, and 30-inch diameters and are laminated with ebony star formica on the bearing surface. The tube clamps feature unbreakable knobs and stainless steel hardware and require no tools to secure the truss tubes.

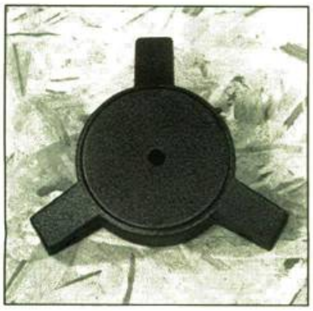
AstroSystems, Inc., 1109 Kimbark Street, Longmont, CO 80501, (303) 678-5339. Dobsonian side bearings: 18-inch: $99.95; 24-inch: $139.95; 30-inch: $179.95. Lower Truss Tube Clamps (set of 8): $109.95; Upper Truss Tube Clamps (set of 4): $79.95. Free catalog.

3 Portable Pier and Tripod Head

The Porta-Pier (left) weighs 14 pounds but will carry up to 50 pounds, breaks down with no tools, and packs to a space 5" x 5" x 44". Each leg slides on and off steel studs and is secured with "tri-rods." The Porta-Pier includes three leg levelers and the Tri-Head assembly that accepts $^{1}/_{2}$x13 threaded bolts. The Tri-Head is available separately as the TR-5 (right) for those who wish to build their own tripods. The 1-pound TR-5 head is made of cast aluminum and has a 4"-diameter top surface and a $^{3}/_{8}$" hole in each of the three knuckles. The TR-5 also includes instructions on how to build your own tripod for under $20.

Astronomical Innovations, P.O. Box 14853, Lenexa, KS 66285, (913) 894-5775. PP-10 Porta-Pier: $124.95; TR-5 Tripod Head: $29.95.





4 New Celestron Spotting Scopes

Celestron has unveiled six new spotting scopes designed for nature and sporting applications. All feature multi-coated optics and a built-in tripod adapter. One of the models, the 20x60 ED (pictured), also features low-dispersion ED glass.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (213) 328-9560. 20x60 Spotting Scope: $658; 20x60 ED: $998; 30x60 Spotting Scope: $658; C60 RC Spotting Scope: $418; C60 RC Zoom Spotting Scope: $598; S-50 Spotting Scope: $198.

5 Space Program Photos and Memorabilia

Houston Space Products has introduced a complete line of NASA items. Their new catalog contains hundreds of products, including color prints, VHS videos, mission patches from all Apollo and Shuttle flights, and commemorative coins. Actual photos (not laser prints) are made directly from NASA negatives.

Houston Space Products, 2437 Bay Area Boulevard, Suite 123, Houston, TX 77058. 8x10 photos: $14; 20x24 photos: $60; mission patches: $4 (small), $8 (large); coins: $8. Send $3 for a complete catalog (refundable on first order).

6 Zeiss 20x60S Stabilized Binoculars

ZEISS
West Germany

These high-power binoculars feature prisms mounted on a suspension system that allows the optical components to sway, compensating for the shaking of the user's hands. The result of the floating optics is a steadier image. The 20x60S is purely mechanical and uses no batteries or electronics. It employs Zeiss T* multilayer coatings and an internal focusing system. It weighs 56 ounces and comes with rubber armoring and an aluminum case.

Carl Zeiss Optical, Inc., 1015 Commerce Street, Petersburg, VA 23803. $4,725. For free binocular buying advice, call Zeiss' new Consumer Information Line at (800) 338-2984 (ask for extension 291 if you are east of the Mississippi or extension 507 if you are west).

7 Electrim's Smaller, Lighter CCD Imager

Electrim Corporation announces a smaller, lighter, and faster version of their EDC-1000 electronic imager. Its 2" x 2" x 1.1" size and 4-ounce weight makes it easier to attach the EDC-1000 to telescopes and microscopes. The improved electronics can acquire images at 30 frames per second and provide a direct digital output of 192 x 330 x 8 bits in TIFF or PCX format. The EDC-1000 can connect to IBM-compatible computers. Also available are the EDC-1000HR imager with 754 x 488 x 8-bit capacity and the EDC-1000TE, a thermoelectrically cooled version for long exposures.

Electrim Corporation, P.O. Box 2074, Princeton, NJ 08543, (609) 683-5546, FAX: (609) 683-5882. EDC-1000: $400.

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Available in 8" 1200mm F/6.3, 8" 2000mm F/10, 10" 1600mm F/6.3 or 10" 2500mm F/10 configurations the new LX100 and LX200 Schmidt-Cassegrains advance the state-of-the-art.

LX100 SERIES

Meade optical tube assembly with SMC super multicoatings, heavy duty fork arm equatorial. Smart Drive PPEC RA motor drive with ECC hand controller for drive correction at 2x speed and image centering at a fast 32x speed. Factory Package Includes; F/6.3 or F/10 optical tube, ECC, 6x30 (8") or 8x50 (10") finder, 26mm eyepiece, 1¼" diagonal, AC adapter, DC car-cord, AA battery pack, field tripod, wedge (8"), Superwedge (10") and foam fitted carrying case.

LX100 8" .. $1695 LX100 10".... $2395

LX200 SERIES

The new LX200 series offers, for the very first time, an easy to use, affordable, fully computerized slewing telescope. For "painless" observation simply align the telescope (using the LX200 computer) and enter any of the 747 objects contained in its built-in library and the LX200's PPEC Smart Drive will automatically slew to that object at an incredible 8° per second. To take great astronomical photos just add the optional equatorial wedge for accurate polar axis tracking.

LX200 8" .. $1995 LX200 10".... $2295

Wedge (8") .... **110** Superwedge (10") **395**

Additional Object Library - adds 8000 CNGC objects to the LX200's built-in computer library **99**

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THE PREMIER SCHMIDT-CASSEGRAIN TELESCOPE FOR ASTROPHOTOGRAPHY

8 inch 2000mm F/10 diffraction limited optics with Meade's exclusive SMC super multi-coatings PPEC computerized permanent Periodic Error Correction Smart Drive motor drive system which operates from AC, DC or AA batteries and offers the ultimate in tracking accuracy.

1739

FACTORY PACKAGE INCLUDES:
Optical tube, Smart Drive, 26mm & 12.4 mm Super Plossl eyepieces, 9x60 RA polar illuminated finder, 2/1¼" diagonal, ECC hand controller, field tripod, equatorial wedge, AC adapter, AA battery pack, case. *List Price Over $2900,* **Limited Supply**

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All Complete Factory Packs	2080 *8 Inch*	2120 *10 Inch*
40 SD F/10 **Smart Drive**	1279	--
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Super Wedge option for 2120 Premiers	259.95	

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2120A 10 inch F/10 SCHMIDT-CASEGRAIN

Without doubt this is the best value large aperture Schmidt-Cassegrain scope available today. It features Meade's renowned 10 inch 2500 mm focal length F/10 optical tube, heavy duty fork arms and an AC 5.75" worm gear RA drive system for accurate tracking.
COMPLETE FACTORY PACKAGE;
Optical Tube, Drive System, 8x50 finder, 1¼" diagonal, 25mm MA eyepiece, Equatorial Wedge and Field Tripod **$1379**

2120B *WITH SMC MULTICOATINGS*
The same as the 2120A but with SMC multicoatings for greatly improved light transmission and enhanced image quality **$1449**

2045D *"The truly portable scope"* ...... **SPECIAL**
4 inch 1000mm F/10 optical tube with SMC multicoatings, equatorial fork mount with reversible DC motor drive & table tripod, 5x24 finder, 1¼" diagonal, 25mm eyepiece and AA battery pack.
Case for 2045D ...... **68.95** Tripod & Wedge **235**

2080A *"Perfect for the beginner"* .... **SPECIAL**
8 inch 2032mm F/10 Schmidt Cassegrain optics equatorial fork mount with motor drive, **wedge, tripod,** 6x30 finder, 1¼" diagonal,25mm eyepiece.
2080B with SMC multicoatings **1149**

STARFINDER NEWTONIANS

The new Starfinder telescopes represent the best value in Newtonians available today. Each Starfinder telescope features Meade's hand figured optics, a precision equatorial mount with integrated motor drive, setting circles & stand. All include #71 rack-and-pinion focuser, 6x30 finderscope and 25mm eyepiece

STARFINDER 6	6 Inch F/8	**499.95**
STARFINDER 8	8 Inch F/6	**599.95**
STARFINDER 10	10 Inch F/4.5	**699.95**
STARFINDER 16	16 Inch F/4.5	**CALL**

Includes heavy duty sealmaster bearing mount and combination 1¼/2 inch rack-and-pinion focuser

STARFINDER ACCESSORIES

Dust cover for Starfinder 6/8/10	**29.95**
#55 Manual Declination Control	**79.95**
#43 Drive Corrector - powers scope from 12v DC & provides RA drive correction for photography	**84.95**
#47M Dual-Axis Drive Corrector - similar to #43 but includes DEC motor & hand controller	**299.95**

4420 NEWTONIAN

#1 Top Rated by Astronomy

The Meade 4420 is the perfect telescope for the beginner. Its large 4½ inch aperture optical tube & equatorial mounting make it ideal for planetary, deeper space observation or astrophotography. A 1¼ inch rack-and-pinion focuser, 5x24 finderscope and 25mm (36x) eyepiece and full height tripod are included.

SPECIAL PRICE

DS-10A *10" F4.5 Equatorial Newtonian Includes RA Motor Drive* **$628**

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Each of these fine instruments is matched to a Meade LXD 600 or 700 equatorial mount & metal field tripod. This brand new design features massive polar & dec. castings, eight ball bearings, and ultra-precise worm drives

102ED 4 Inch F/9 .... **1795**
Includes; Optical tube, 2.7" focuser, 2" diagonal, 8x50 finderscope 26mm New Super Plossl eyepiece, LXD600 equatorial mount, heavy duty metal tripod

127ED 5 Inch F/9 .... **CALL**

152ED 6 Inch F/9 .... **CALL**
Same as 102ED but with LXD 700 mount

178ED 7 Inch F/9 .... **CALL**
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- 3½"1000mm F/11 optics
- 5x21 erect image finder
- 45° erecting diagonal
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Camera Adapter	**34.95**
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2045S 4" SPOTTING SCOPE.... 386

40% More Light Gathering Than A 3½ Scope

The 2045S uses Meade's astronomical grade 4" 1000mm F/10 Schmidt-Cassegrain optics. It features SMC multi-coatings and micrometer focus plus a 25mm (40x) 1¼" eyepiece, erect image diagonal & 5x21 finderscope.

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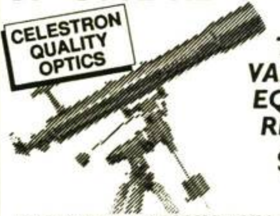

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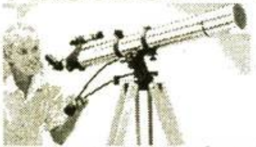

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This attractive 3.1 inch refractor features a solid Brass 910mm F/11 optical tube with Brass focuser, Altazimiuth mount with slow motion controls, 6x30 Brass finder, 18mm (51x) Ortho eyepiece, 1¼" 45° erect image diagonal, Beech wood adjustable tripod & accessory tray.

C60 2.4" Alt-Azimuth Refractor	119.95
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NEWTONIANS

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4½ inch 900mm F/7.9 Equatorial Newtonian with field tripod, 25mm 1¼" (36x) eyepiece, 5x24 finderscope **$438**

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6 inch 750mm F/5 wide-field Equatorial Newtonian with Super Polaris mount, field tripod, 18mm (42x) eyepiece, 6x30 finderscope **$729**

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3½" 1000mm F/11
Use as a spotting scope telescope or camera lens
Includes: 33x eyepiece, 8x20 erect finder, 45° erect prism, fitted carrying case.

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SCHMIDT- CASSEGRAINS

SUPER POLARIS C8

The Celestron Super Polaris C8 has long been Europe's most popular Schmidt-Cassegrain telescope. These fine instruments combine Celestron's famous 8 inch 2032mm F/10 optics with the versatile and easy to use Super Polaris equatorial mount.
FACTORY PACKAGE INCLUDES
8 inch F/10 optical tube, Super Polaris equatorial mount with illuminated polar axis finder, 5x24 finderscope, 25mm Kellner eyepiece, star diagonal, adjustable field tripod & case.
FOCUS CAMERA SALE PRICE **$898.95**

Super Polaris C8 with Starbright	$1049.95

SPECIAL BONUS

Purchase any Super Polaris C8 scope and get a Celestron single-axis motor drive (list price $160) for only **$59.95**

CLASSIC 8

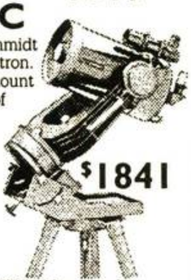
INCLUDES STARBRIGHT & RUBBERIZED TRIPOD

The Classic is the latest in a long line of fine Schmidt-Cassegrain telescopes from the company that pioneered top quality commercial telescopes.
COMPLETE READY TO USE PACKAGE INCLUDES:
8 inch 2032mm F/10 optical tube with Celestron's exclusive **Starbright** coatings, rugged swing fork equatorial mount with precision spur gear drive, 25mm Kellner eyepiece, 6x30 finder, 1¼" star diagonal, wedge and **Rubberized Field Tripod** **$1197**

POWERSTAR PEC

The new Powerstar PEC features Celestron's famed 8 inch Schmidt Cassegrain optics with **Starbright** coatings, PEC periodic error correction DC servo drive system & Byers worm gear for improved tracking accuracy, 30mm Plossl eyepiece, 6x30 finderscope 1¼" Star Diagonal, case, wedge & rubberized tripod **$1519**

ULTIMA 8 PEC



The state of the art 8 inch Schmidt Cassegrain telescope from Celestron. It features a rugged swing fork mount with carrying handles for ease of set up, a massive cast polar shaft with 4" ball bearings, 7½" Byers worm gear drive & PEC periodic error correction drive system for the ultimate in drive accuracy. **$1841**
COMPLETE FACTORY PACKAGE INCLUDES:
8 inch 2032mm F/10 optical tube with Starbright coatings, PEC drive, hand controller, 30mm & 7mm eyepieces, 8x50 finderscope, 1¼" star diagonal, case, wedge & rubberized tripod

ULTIMA 11 PEC

The ultimate 11 inch Schmidt-Cassegrain telescope. The Ultima 11 includes 11" 2800mm F/10 optical tube with **Starbright** coatings, rugged swing fork equatorial mount with PEC motor system featuring a 7.54 Byers worm gear drive, hand controller, 8x50 finder, 2" star diagonal, 30mm & 18mm eyepieces, heavy duty wedge, tripod and case. **CALL**

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Bausch & Lomb 4000	77.95
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NGC MAX computer system with 8100 objects and guide mode, complete	769.95

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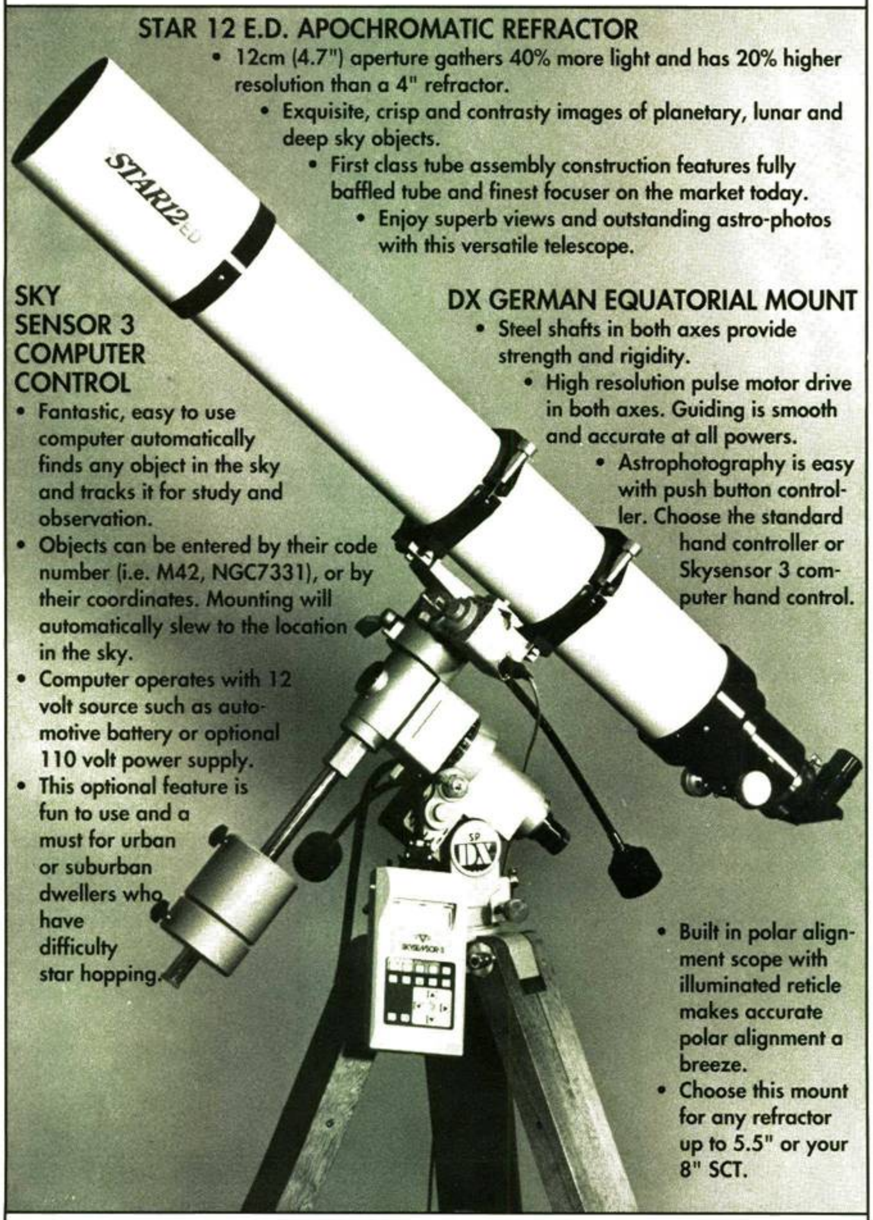

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Meetings & Events

July 31 – August 2
Stellafane, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

August 7–9
CAFTA Telescope Makers Contest, Parc régional des Iles, St-Timothée, near Valleyfield, Québec. Contact: Société d'Astronomie de Montréal, C. P. 206, Station St-Michel, Montréal, Québec, Canada H2A 3L9. Phone: (514) 728-4422.

August 7–9
3rd Annual Southern Michigan Universal Regional Festival of Stargazers, near Clare, Michigan. Sponsored by the Genesee Astronomical Society. Contact: Richard Walker, c/o Robert T. Longway Planetarium, East Kearsley Street, Flint, MI 48503. Phone: (313) 627-9524.

August 8
Prairie Astronomy Club Star Party, Hyde Observatory, Holmes Park, Lincoln, Nebraska. Sponsored by the Prairie Astronomy Club. Contact: Lee Thomas, P. O. Box 80553, Lincoln, NE 68501. Phone: (402) 483-5639.

August 15
Annual Star Party, Winchester Canyon Gun Club, Santa Barbara, California. Sponsored by the Santa Barbara Astronomy Club. Contact: Clyde Kirkpatrick, P. O. Box 3702, Santa Barbara, CA 93130. Phone: (805) 966-3695.

August 22
Ohio Turnpike Astronomers Association Convention, Indian Hill Observatory, Chagrin Falls, Ohio. Contact: Chagrin Valley Astronomical Society, P. O. Box 11, Chagrin Falls, OH 44022. Phone: Bob Modic at (216) 636-5789.

August 22
Tidewater Summer Star Party, Tidewater Community College, Portsmouth, Virginia. Contact: Tidewater Community College Astronomical Society, Physics Department, State Route 135, Portsmouth, VA 23703. Phone: Aubrey Hartman at (804) 484-2121, ext. 235.

August 27–30
5th Annual Oregon Star Party and Campout, Ochoco Mountains, Oregon. Sponsored by the Rose City Astronomers. Contact: Chuck Dethloff, 15111 NW Oakmont Loop, Beaverton, OR 97006. Phone: (503) 629-2145.

August 27–30
2nd Annual Great Plains Star Party, Flint Hills, 75 miles southwest of Kansas

City, Kansas. Sponsored by the Kansas Astrophotographers and Observers Society. Contact: Bob Nederman, 9200 Westbrooke Drive, Overland Park, KS 66214. Phone: (800) 473-4382.

August 27–31
Mount Kobau Star Party, near Osoyoos, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

August 28–29
East Coast Star Party, Coinjock, North Carolina. Contact: Kent Blackwell, 1169 Old Kempsville Road, Virginia Beach, VA 23465.

August 28–29
Southern Idaho Regional Star Party, Bruneau Sand Dunes State Park, Mountain Home, Idaho. Contact: Boise Astronomical Society, Inc., P. O. Box 8386, Boise, ID 83707.

August 28–29
Starfest '92, Riverplace Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5. Phone: (416) 761-1798.

August 28–30
The Conjunction, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Jack Megas, 311 Surrey Road, Springfield, MA 01118.

August 28–30
Weekend under the Stars, Fox Park, Wyoming. Sponsored by the Cheyenne Astronomical Society. Contact: Marty Curran, 6614 North College #G, Cheyenne, WY 82009. Phone: (307) 635-5944. (Listed in May issue as September 25-27.)

August 29
Summer Star Party, Strawberry Mountain, Ohio. Sponsored by the Black River Astronomical Society. Contact: Mike Harkey, 1631 Maple Drive, Lorain, OH 44052. Phone: (216) 288-8556.

August 29–31
Nova East '92, Fundy National Park, New Brunswick. Contact: Douglas Pitcairn, 13 Ferguson Road, Dartmouth, Nova Scotia, Canada B3A 4J8. ☐

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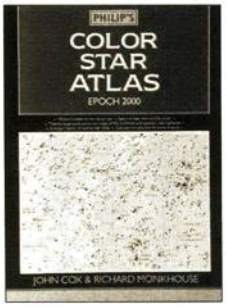

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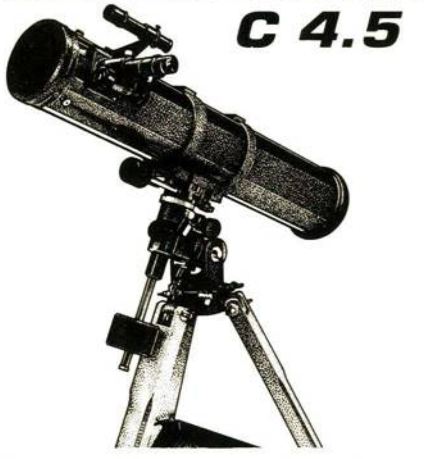

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Readings & Resources

Volcanic Twilights (page 36)

Sunsets, Twilights, and Evening Skies, by Aden and Marjorie Meinel, (Cambridge University Press, 1983). A must for any follower of atmospheric phenomena.

The Nature of Light and Color in the Open Air, by M. Minnaert, (Dover Publications, 1954). Ditto.

Interplanetary Fugitives (page 30)

Introduction to Asteroids, by Clifford J. Cunningham (Willmann-Bell, Inc., 1988). For advanced amateurs, this book includes advice about observing asteroids and profiles of the professionals who study these minor planets.

Asteroids: Their Nature and Utilization, by Charles T. Kowal, (Halstead Press, 1988). Describes asteroids' orbits, physical characteristics, and origins.

COBE's Big Bang (page 42)

"Too Smooth: COBE's Perfect Universe," by Jeff Kanipe, ASTRONOMY, June 1990. Describes the early results from the Cosmic Background Explorer satellite, which showed no evidence for ripples in the microwave background radiation.

Staging a Moon Shot (page 62)

The Backyard Astronomer's Guide, by Terence Dickinson and Alan Dyer, (Camden House, 1991). Contains extensive chapters on astrophotography.

Astrophotography for the Amateur, by Michael Covington, (Cambridge University Press, 1991). A recently revised introduction to all the basic techniques.

Universal Tripod (page 76)

Build Your Own Telescope, by Richard Berry, (Charles Scribner's Sons, 1985). Describes five do-it-yourself telescope projects, including the construction of Dobsonian rocker boxes and tripods.

CREDITS

Cover: illustration by Robert Eggleton; ***inset:*** Peter French; ***p. 4:*** NASA/JPL Multimission Image Processing Laboratory; ***p. 16:*** NASA/JPL Multimission Image Processing Laboratory; ***p. 18, top:*** NASA; ***middle:*** Philippe Crane and NASA/ESA; ***bottom:*** NASA; ***p. 21, left:*** Center for Extreme Ultraviolet Astrophysics, University of California — Berkeley; ***right top and bottom:*** UA Steward Observatory; ***pp. 22-29:*** all photos courtesy California Association for Research in Astronomy; ***pp. 30-31:*** illustration by Michael Carroll; ***pp. 32 and 34:*** illustrations by Lee Vande Visse; ***pp. 36-37:*** William Livingston; ***p. 38, top:*** Alister Ling; ***bottom series:*** Alan Dyer; ***p. 39:*** illustrations by Phil Kirchmeier; ***p. 40:*** Daniel V. Dungla; ***p. 41:*** Alister Ling; ***pp. 43:*** NASA/Goddard Space Flight Center; ***p. 44:*** NASA; ***p. 57:*** illustrations by Lee Vande Visse; ***pp. 58-59:*** illustrations by Thomas L. Hunt; ***p. 62:*** Andrew Steinbrecher, 16-inch Newtonian, Panatomic-X film, 1/125-second exposure; ***p. 63:*** Darla Gawelski; ***p. 64, left:*** Darla Gawelski; ***right:*** Jeffrey Jones, 200mm f/4 lens, Tech Pan 2415 film, 1-second exposure; ***p. 65, left:*** Robert Luffel, 8-inch SCT; ***right top and bottom:*** Darla Gawelski; ***p. 66:*** Brian Tkachyk; ***p. 67, left:*** Jim Rouse, 8-inch Newtonian, High Contrast Copy film, 2-second exposure; ***right:*** Darla Gawelski; ***p. 68:*** Jack B. Marling, 17.5-inch f/4.5 reflector, Fujichrome 400 film, 15-minute exposure; ***p. 69:*** Richard W. Jakiel, 20-inch f/4.5 reflector at 315x with UHC filter; ***p. 70, left:*** Richard W. Jakiel, 20-inch f/4.5 reflector at 175x; ***pp. 70-71:*** Jack B. Marling, 24-inch f/15 Cassegrain, 10-minute exposure; ***p. 71, top:*** Jack B. Marling, 24-inch f/15 Cassegrain, Fujichrome 400 film, 30-minute exposure; ***bottom:*** Martin C. Germano, 8-inch f/10 SCT, hypersensitized Tech Pan film, 5-minute exposure; ***p. 72, top:*** Jack B. Marling, 17.5-inch f/4.5 reflector, Fujichrome 400 film, 15-minute exposure; ***bottom left:*** Richard W. Jakiel, 13.1-inch f/4.5 reflector at 269x; ***bottom right:*** Jack B. Marling, 24-inch f/15 Cassegrain, Fujichrome 400 film, 3.5-minute exposure; ***p. 73:*** Martin C. Germano, 8-inch f/10 SCT, 103a-F film, 7-minute exposure; ***pp. 76-78:*** Darla Gawelski; ***p. 79, left:*** Darla Gawelski; ***right:*** M. Leon Knott; ***p. 83, top:*** Jacques Guertin, taken in Java in 1983; ***bottom:*** Ron Gattie, 8-inch SCT at f/11, Kodachrome 64, 1/8-second with hydrogen-alpha filter; ***p. 84, top left:*** George Greaney, 5-inch refractor at f/5.9, hypersensitized Tech Pan film, 75-minute exposure; ***bottom left:*** Ronald W. Kohl, 20-inch Cassegrain, Photometrics STAR I CCD camera; ***top right:*** Bill Sterne, 50mm lens at f/1.2 lens, High Speed Ektachrome film; ***bottom right:*** Steve Quirk, 10-inch f/5.8 reflector, hypersensitized Ektar 1000 film, 20-minute exposure; ***p. 85:*** Bill and Sally Fletcher, 8-inch f/4.5 reflector, Fujichrome 400 film, 70-minute exposure.

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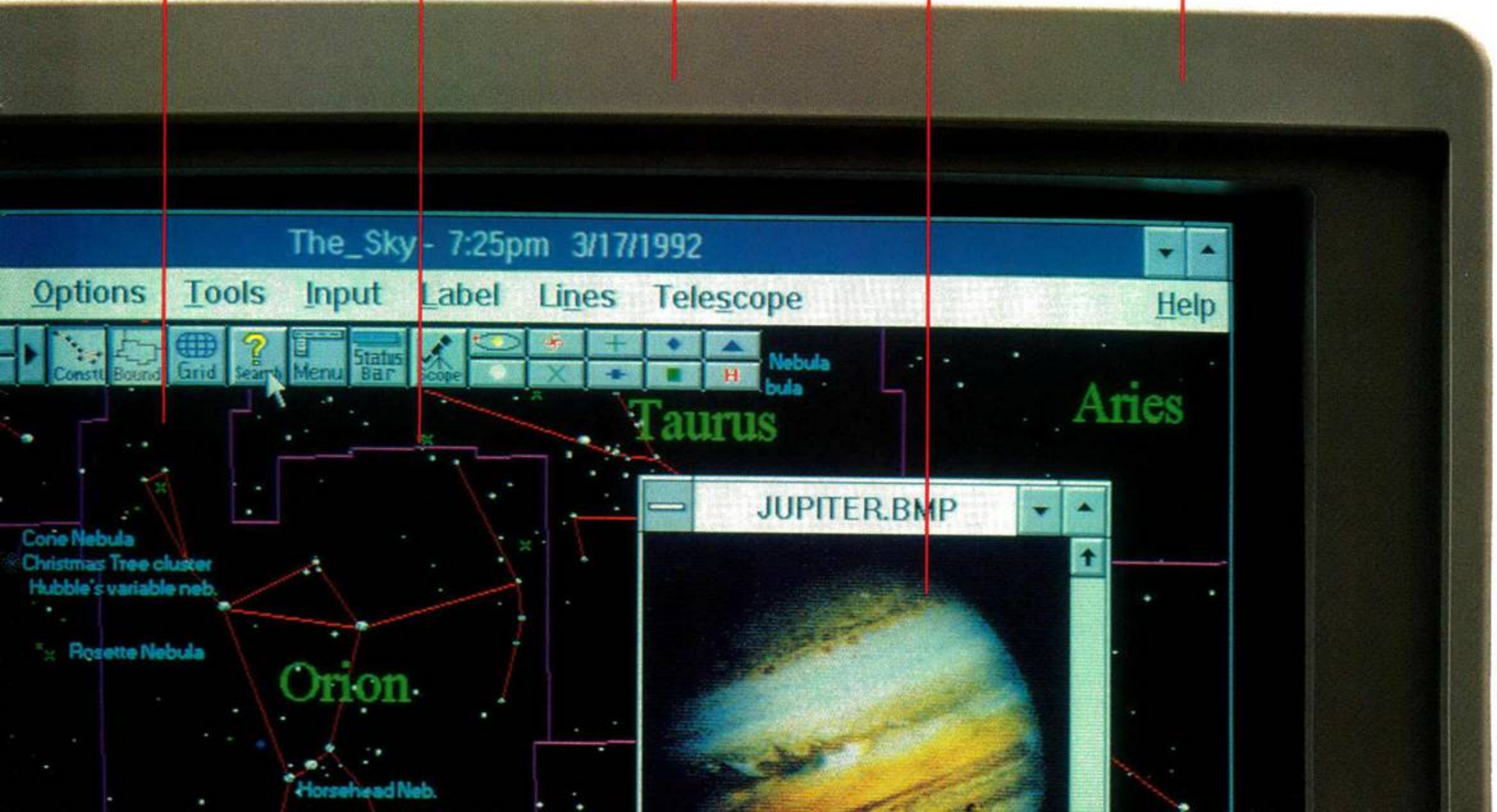
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Ultima 8 (PEC)	$1795
SPC 8 w/ motor drive	$895
SPC 8 w/Starbright	$1024
COMPUSTAR 8	$2585
POWERSTAR (PEC) C8	$1498
CLASSIC 8,Wedge STARBRIGHT, Tripod	$1099
C040 Refractor Tripod (2) Eyepieces	$69
C60 .... $118 C60E	$188
Firstscope 80 .... $443 (in brass)	$725
SP-C80	$606
Refractor (SP-C102)	$895
Fluorite Refractor (SP-C102F)	$1695
Telephoto 500mm F5 6	$289
Telephoto 1000mm C90	$319
C4 5	$398
SPC6	$718
Vixen 4 1/4" Alt Reflector	$245
Vixen 4 1/4"EQ Reflector	$289
Vixen 80mm Refractor	$375
Vixen 90mm Refractor	$430

SPOTTING SCOPES

C90 C90M/C C90 M/C Armored	CALL
20x60 .... $358, 30x60	$358
20x60ED $518,C60Zoom	$318
C60R $219 C65	$119
SS80 w/2 eyepieces	$339
Photographic Tripod .... $94 Mini Tripod	$24
Shoulder Mount	$59

BINOCULARS

Monocular 8x25....$37, 8x25 mini....$64, 10x25	$84
Waterproof 7x50 10x50 .... $195 7x50 Sport	$75
10x50 PRO...$118 7x50 PRO...$114 12x50 PRO	$149
Ultima 7x42 8x32....$172 ea. 8x56	$185
11x80M/C...$290 15x89M/C...$295 20x80M/C	$299
20x100	$895
Fixed Focus 8x40 WA 7X50WA 10x50WA	$64
7x50 .... $65 Armored 10x50 (Vixen)	$66
BINOCULAR NECK STRAP (Wide)	$10

OPTICAL TUBE ASSEMBLIES

C80 C4 5	ea $279
8" Optical Tube Assem. (Blk or Orn)	from $545
C11 .... $1849 C14	$3899

ULTMA EYEPIECES

5, 7.5 12.5, 18, 24mm 2xBARLOW (11/4")	ea $62
30 35 42mm	ea $86
15 19 23mm WA	ea $102
45 60mm 2"	ea $159
80mm 2"	$238
OR 5, 6, 7, 9, 12mm (96")	ea $36
KE 10mm 18 25 30 40 (96")	ea $29
Zoom 96" OR 8 4 21mm-DELUXE	$99
25mm K 11/2" Multi-Coated	$35

Terrestrial Eyepiece 96"	$17
OR 1 1/4" 5 6 7 9 12mm	ea $45
PL 1 1/4" 36mm 45mm	$59
Zoom OR 11/2" 8 4 21mm	$195
18 25mm 2" SPECIAL PURCHASE	ea $74
Coma Corrector Photo-Visual 1 1/4" - 2"	$175
Micro Guide Eyepiece	$133

T-RINGS

(State Camera Make Model) All $10 EA OR (2)	for $18
2 1/4" Format	$159

ACCESSORIES

AC Adapter (PEC)	$22
Accessory Case	$43
Barlow Lens 2x96"	ea $26
Barlow Lens 2x1 1/4"	ea $39
Barlow Lens 2x2"	ea $85
Battery (Ill Reticule)	$2.95
Binocular Tripod Adapter	$14
Car Batt. Adapter Ultima (PEC)	ea $19
Car Window Mount	$50
Carrying Case - Powerstar 8 Custom	$139
Counterweight Bar Assem -8" ..$59 11"	CALL
Counterweight Set - 8" (Standard)	$48
DC Inverter (110V)	$74
Drag Erect Image - 45° 96" ....$42 45° 1 1/4"	$46
45° 96" to 1 1/4"	$45
DEC Motor - Powerstar Classic 8	ea $92
DEC Motor - 11"	$79
DEC Motor C8 Sup C8 Classic 8	$99
DEC Motor (PEC) 8/11	$92
Deluxe Lat Adjuster (DLA) C8	$30
Dewstar (Lens Shade - 8")	$25
Advanced Astro Master (Several Models)	from $489
Drive Corrector - Heavy Duty	$359
C8 Quartz Sing Axis	$195
Quartz Dual Axis	$243
Expanding Bushing - 96" to 1 1/4"	$14
Filter (All Colors) 2"	ea $19
Filters #1A 8 12 15 21 23A 25 38A 47 56 58 80A 82A 96ND 50% 96ND 25% 96ND 13% Polarizing	ea $10
Filter Sets (Set of 6) .... $59 (Set of 12)	$118
Filter - Series 5 or 6 (6 ea. in Set)	$55
Filter Adapter - 96" .... $12 1 1/4"	$16
Finderscope 8x20 for C90-erect image....$54 BKT	$12
Finderscope R/A 5x24...$39 5x24 STG ...$29 6x30	$32
8x50 .... $49 16x70R/A w/pol ill	$189
R/A w/Polar Align Reticule - 8x50 Ultima w/BKT	$144
Focus Motor - C8,Classic 8, PWR STAR	$95
Focus Motor (PEC) 8/11 11/14	$98
MFFT 55	$129
Illum Projection Reticle - 1 1/4"	$134
Image Corrector - 1 1/4" OR .96	$24
Large Accessory Ring (LAR) C90	$21
Lens Shade - C90.....$54 C8.....$25 C11	$139
LPR Filter(Nebular #2.....$129 #3.....$42 #5	$79
#7.....$89 "A".....$49, "B".....$59 "C"	$109
Motor Drive-for C4 5 w/Dr Single Ax.-SP (DC)	ea $155
Motor Drive S A (AC) Pol/Sp	$88
Motor Drive w/Dr. Dual Axis SP (DC)	$253
Multiple Ocular Holder 96"....$49 1 1/4"	$124
Off Axis Guiding System $127 Guider Body (Only)	$59
Photo Tripod Adapter 8"	$50
Photographic Tripod Deluxe Slow Motion Controls	$43
Piggyback Mount 8" $33 11 14	$44
Piggyback Mount SPC 80 SPC 102 SPC6	ea $39
Polar Axis Finder w/Illum (for C4 5)	$52
Polar Axis Finder - SPC6 - C80	$66
Polar Filter Set - 965	$36
Polarizing Filter Set - 1 1/4"	$42
Porro Prism - 965....$39 Porro Prism 1 1/4"	$43
Radial Guide Assy Off Axis	$99
RFA (Rich Field Adap)	$79
Refractor Accessory Ring	$18
Reducer/Corrector Lens f6 3	$135
Reducing Bushing = 1 1/4" to 96"	$16
Filter Set - Series 5 (six) .... $49 Series 6 (six)	$49
Skylight Filter Model #1 (C90s)....$31 #2 (8/11/14)	$36
Solar Filter - C90 C102 C4 5	$68
5" Off Axis - C11....$109, C8....$112, C60 C80	$42
Star Diagonal - 96"	$19
Star Diagonal 1 1/4" w/Multicoatings	$39
Star Diagonal (Mirror) 2" Deluxe Adjustable	$219
Star Diagonal 2" - Multi-Purpose	$215
Stereo Binocular Viewer	$418
Super Polaris Half Pier	$105
Super Polaris Mt & Tripod	$449
Tangent Ass'y	$195
Telecompressor Lens 15 0r f7 5	$39
2 1/4" Camera Adapter (Specify 2 1/4" Camera)	$149
T-Adapter (8/11/14) C90 Zoom Master/C60	ea $22
T-Adapter/Tele Extender - Refractors C4 5, C6, C60	$32
T-C 16mm Adapter $28, 6x6	$58
Table Top Mount - C65	$20
Tele Extender.....$22 T-Adapter (Refractor/Newt)	$38
Tripod - Adjustable 8" - Armored	$209
C8 Tripod (Oak) $129 11/14	$468
VSP (Vibration Suppression Pads)	$38
Visual Back - 1 1/4"	$26
Wedge - C8.....$85 Heavy Duty 8"....$198 11/14	$369
Tilt Plate 0 Degrees	$75

PUBLICATIONS

Owners Manuals, Acc. Catalog	ea $5
Binocular Buyers Guide Book by Alan Hale	$9.95
Sky Maps	$12
Star Atlas (Northern Hem.) 20000	$16.50

MICROSCOPES

#2106.... $105, #2101, 2103, 2104	ea $74
#2108.... $149, #2009	$174

MISCELLANEOUS

Lens Caps	ea $50
Brass C50 (List $500)	$195
Fluorite SPC80F Special Unit	$1399

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Telrad w/base (Anti-Fog Coated)	$38
Adlerblick 7x50 M/C - 10x50 M/C	$269
Vogel - Digitrak Drives, Inverters-SPECIALS-	CALL
Questar Tripod H-D Field Model	$289
Schmidt Camera CELESTRON	$1245
20" f5 PARKS MFR.	CALL
THOUSAND OAKS SOLAR FILTERS	CALL
Glass-Full aperture 8 in.	$79
Astroscan - EDMUND 4 1/4"	$287

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Meade

TELESCOPES

97D....$289, 97E....$303, 97ER Spotting Scope	$336
2045 Spotting Scope	$398
2081 Spotting scope 8" f10 .... $719 f6 3	$749
312 3 1" (80mm) f/11 Alt. Refracting Telescope	$369
323 with Equatorial Mount	$418
2 4" (60mm) Alt. Refracting Telescope	$89
2 4" (60m) Equatorial Refracting Telescope	$149
#228 2 4" Brass.......$288, #314 3 1" Brass	$624
4420 4 1/2" Reflecting Telescope	$300
SN 6-6" DVII/NEwt. f4.5	$449
SN8-8" SCH/NEWT f4 O T	$499
Newt. Reflectors 6", 8", 10", 16"	CALL
2060 16" f/10 SCH/CASS	$9999

BINOCULARS

11x80, 20x80 M/C	$353
Equatorial Wedge plus Tripod 2045	$232
Super Wedge 10"	$349
Equatorial Wedge for Model #2080, #2045	$85
Equatorial Wedge for Model #2120	$98
Field Tripod for Model #2080, #2120	$205
Field Tripod for Model #2080(Oak))	$129
Photo Tripod "Superstar"	$95
Altazimuth Adp. for Field Tripod (#2080, # 2120)	$18
Fork Mount/Drive 4"....$274 8".... $624 10"	$724
Deluxe Latitude Adjuster 2080	$25
Setting Circle Illuminator System #2080, #2120	$36
LED Map Light 2045, 2080,2120	$26
#605 Magnetic Compass	$10
#607 25' Ext. Cord for use with AC Coverter	$16
Azimuth Control (for Field Tripods for 2080)	$15
#603 DC Cord (25') w/cigarette plug	$16
1200, 1200A Electric Focuser	$118
#671 Wide-Field Adapter System (WFAS complete)	$89
Tele-Compresser Lens only	$39
Tele-Compresser System comp w/Extender Tube	$54
Eyepiece Extender Tube only	$18
Off-Axis Guider Body only	$78
Illum Rct Eyepiece Sys 1.25"	$64
#702A Double Crossline Reticle	$24

#705A Micrometer Reticle	$26
H35mm Crosshair Eyepiece (965)	ea $36
Spotting Scope Adp.Plate 2120, 2120 LX3 5 & 6	$52
Mod. Ach. (965) 9 12 25 40mm	$34
40mm Mod. Achromatic ep 1.25"	$39
1.25" Orthos 4mm, 6mm, 9mm, 12.5mm, 18mm Ocu'rs	$46
Sup Plossi 1 25" 6 4 mm 9 7 mm, 12 4mm	$69
15mm, 20mm, 26mm	$59
32mm, $84, 40mm, 1 25"	$79
56mm, 2"	$144
13 8mm Super Wide 1 25"	$114
18mm 1 25"	$112
24 5mm 1 25"	$112
32mm 2"	$177
40mm 2"	$228
4 7mm 1 25"	$134
6 7mm 1 25"	$124
8 8mm 1 25"/2"	$143
14mm 1 25"/2"	$178
Rotary Multiple Holder 1 1/4"	$124
Eyepiece Holder, 1 25"	$26
#915 Diagonal Prism .965 (90°)	$36
#917 Hybrid Diagonal Prism 965/1 25"	$36
#918 Diagonal Prism .965/1 25"	$36
#919 Diagonal Prism w/threaded Ring 1 25"	$40
#929 2" Diagonal Mirror including eyepiece adapter with 1 1/4" Adapter	$84
#930 Diag Mirror 2" OD Barrel for 2" Focuser Sleeve	$129
#926 Image Erecting Lens (.96)	$19.50
#924 Erecting Prism 1 25"	$56
#928 Erecting Prism System 45°	$46
#912 Roof Prism 965, 90B, 97D, 97E, 97ER	$49
#931 Hybrid 45° Erecting Roof Prism	$49
#965 Photo Vis. Color Fil. & Pol. 1 25" All Col. Avail	ea $11
Set of 6 Photo Visual Color Filters	$60
Set of 6 Photo Visual Filters (965) Thread In	$60
Series VI Drop-In Filter Set (2045, 2080)	$46
Series V Drop-In Filter Set (90B, 97D, 97E, 97ER)	$46
#905 Variable Polarizing Eyepiece System 1 25"	$48
#908 Nebula Filter 1 25" (B)	$55
#910 Nebula Filter 2" (B)	$85
#911 Nebula Filter (rear cell Thread on) (B)	$98
#122 2X Tele-negative Amplifier (for all 8" & 10")1 1/4"	$40
#126 1 1/4" Barlow (2045.4420)	$39
#127 2X-3X Variable Tele-negative Amplifier	$54
#131 2X Tele-negative Amplifier 965 (291, 294)	$36
#140 2X Tele-neg Amplifier (for all 8" & 10") S/C	$61
#581 Sun Shade ST Model SS	$46
#582 Dew Shade for 1070, 2045	$46
C A T for 8/10".....$689 Digital Readout 8/10"	$244
#710 Dew Shield 10" 2120	$108
#712 Dew Shield 8" 2080	$98
#1A Skylight Filter/Dust Seal	$44
#50 Accessory Case	$59
Case (2080)	$89
Case (97SS)	$29
Extra 2lb Weights for 1401 or 1402	ea $20
Tube Balance 2045	$43
#1401 Tube Balance Weight System 2080	$69
#1402 Tube Balance Weight System 2120	$74
Extra Counterweight 25lb, 1"	$66
Extra Counterweight 40lb, 11/2"	$79
#71 Focuser 1 25" ID	$44
$67 Focuser 1 25" ID	$57
#680-#682 Deluxe Focuser 1 25" & 2" ID	ea $88
#59 Adapter Photo Pathfinder only	$22
#60, #61, #62 T-Adapters	$22
#64 T-Adapter only for WFAS	$34
Tele-extender	$22
Tele-extender (Variable)	$36
Basic Camera Adapter 1 25" 965"	$29
Variable Projection Camera Adapter 1 25"	$39
2" Prime Focus Adapter	$39
Prime Focus Camera Adapter (.96)	$20
T-Mount Camera Ring Adp'rs (Spec. Camera & Model)	$10
Extension Tube Set (15mm, 30mm, 45mm)	$39
#708 Piggyback Camera Adapter (3.1)	$36
Piggyback Bracket 2080/2120	$30
Piggyback Bracket 2045	$16
#967 9x60 Polar Illuminated View Finder w/bkt.	$133
Bracket for #541 View Finder (2045)	$12
#634, 6x30 View Finder w/bracket - MTS 6-8	$42
#544, 8x50 View Finder w/bracket - SC8	$76
#781 Electric Motor Drive AD (323, 4420	$79
#55 Manual Declination control	$69
#65RS Manual Declination Cont.	$106
48RS Dual Axis Dr. Corrector Sys.	$369
Electronic Control Center	$229
#43 R A Drive Corrector operates from 12VDC	$81
#46 Dual Axis Drive	$259
#47M Dual Axis Dr. Correctos Sys	$294
#36 Single Axis-Dual Axis Drive Corrector Control	$89
#38 Declination Motor Ass. 2080 LX3, 2120 LX3	$89
#38B Declination Motor Assembly 2080, 2120	$89
#38M Electric Declination System	$89
#39 Declination Motor for LX5, LX6, Premier	$89
#66A Manual Declination Control	$42
#66C Manual Declination Control	$54
Casters (2" Diameter) for 16" (set of 3)	$38
Leveling Screws for 16" (set of 3)	$38
Leveling Screws for 10" (set of 3)	$29
#868 Extension Tube (2"-10", 16")	$20
Vinyl Dust Cover for 16"	$26
Vinyl Dust Cover for 10"	$19
Lens Caps -96 1 1/4".....50¢ ea. 7	for $3
Vinyl Dust Cover pair 6"	$26
Vinyl Dust Cover pair 8"	$36
Accessory Shelf for 6"-8"-10"	$39
Accessory Shelf for 16"	$49
Accessory Shelf for Field Tripod (2045,2080,2120)	$24
#AD-1 Eyepiece Adapter 965, #AD-2 1 1/4"	ea $18

Mirrors, Eq. Mounts - Please call for quotes

TELESCOPES

2045D	$545
CARRY CASE	$66
2045 case	$44

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TSN-3	$689	TS602	$239

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Buyers Guide

3% Credit Charge

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6X30 FMTR-SX	$355	STAR SCOPE (NIGHT IMAGE INT.VISUAL)	$1849
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8X40BFL	$245	10X70 FMT-SX	$439
7x50 MT-SX	$325	16X70 FMT-SX	$559
7X50 MTRC-SX	$375	25X150 MT	$6125
10X70 MT-SX	$395	25X150ED	$7125
7X50 FMT-SX	$365	TRIPOD BKT.	$14
7X50 FMTR-SX	$390		

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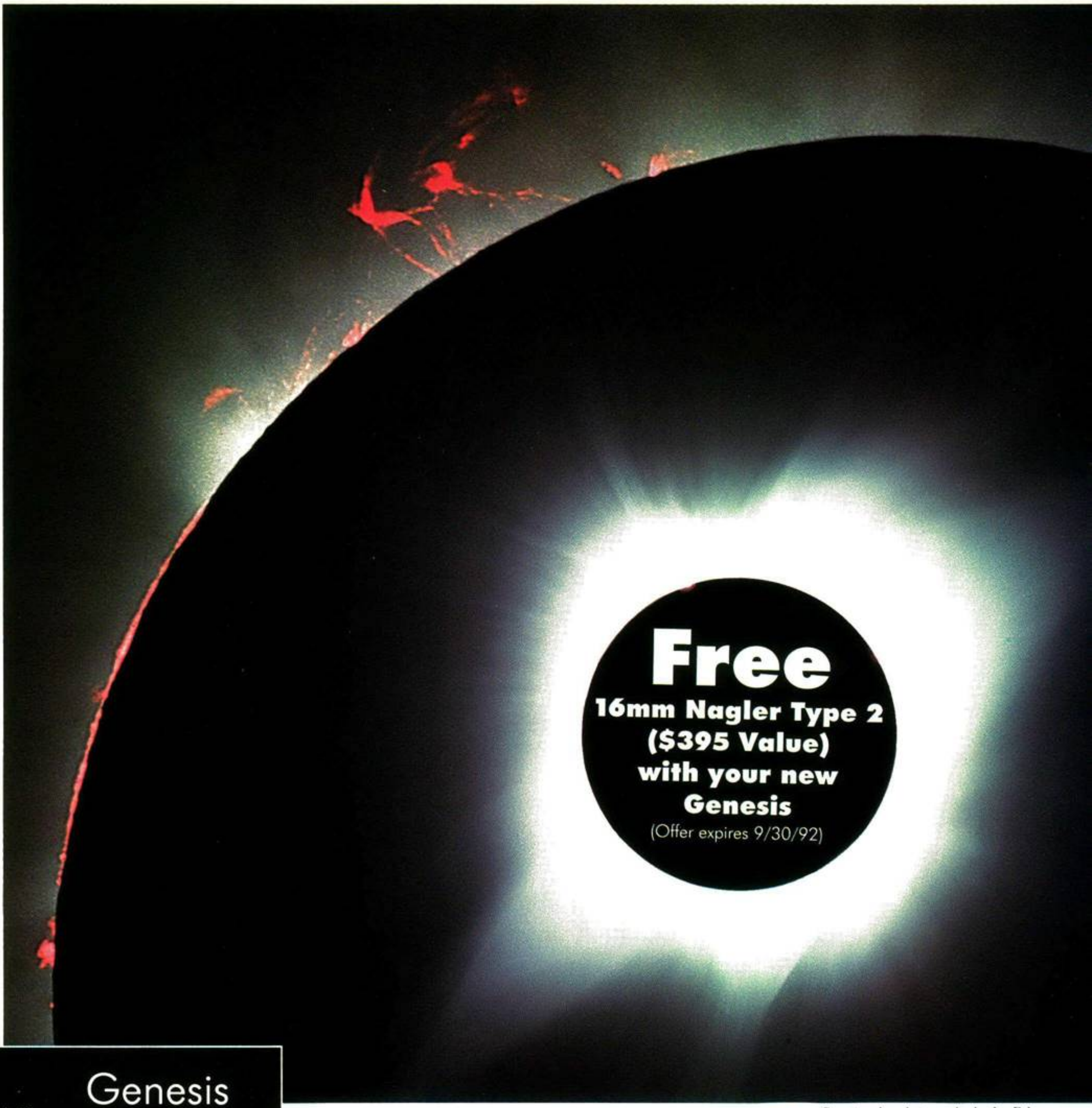
GENESIS



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Genesis
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Genesis solar photography by Joe Folmer.

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Don't wait for another eclipse to view spectacular solar activity. The new Genesis Solar Kit safely turns this 500mm, f/5 APO into the optical equivalent of our fabulous "Solaris". Add a Daystar H-a filter to the Genesis Solar Kit and start viewing dynamic solar phenomena today. Call us for details.

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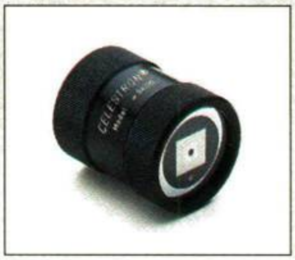
CELESTRON ACCESSORIES ENHANCE THE ENJOYMENT OF YOUR TELESCOPE

COMA CORRECTOR—controls coma and astigmatism in Newtonian telescopes without increasing the focal ratio of your telescope. It works well with mirrors from f/4 to f/6 both photographically and visually. Fully multi-coated. Fits 1-1/4" and 2" focusers and off-axis guiders with the adapters supplied. Made in Germany.

VIBRATION SUPPRESSION PADS—reduce telescope vibration caused by windy conditions, an unsteady mount or an accidental bump. The three pads fit between the bottom of the tripod legs and the ground (or any surface) and substantially reduce vibration time and amplitude.

ORTHOSCOPIC EYEPIECES—while sometimes taking a back seat to more expensive and sophisticated eyepieces, Orthoscopics are still one of the best designs with excellent aberration correction at an economical price. Five focal lengths (5,6,7,9,12mm) in both .96" and 1-1/4" sizes.



MFFT-55—is a focusing aid designed to allow astrophotographers to accurately evaluate their telescope's focal plane in three main areas of interest: focus, collimation (focal plane squareness) and curvature of field. You can focus on and off axis in four quadrants. Made in Belgium.

DELUXE TELE-EXTENDER—recently introduced, this tele-extender for Schmidt-Cassegrains allows the use of 1-1/4" eyepieces with large diameters such as Ultima eyepieces. It is used for eyepiece projection photography of solar system objects.

2" MIRROR STAR DIAGONAL—significantly upgraded with improved optical quality and mechanical design, this diagonal is one of the best on the market that allows the use of 2" eyepieces with Schmidt-Cassegrains. The mechanical housing is precision machined with smooth edges. An adapter to accept 1-1/4" eyepieces is included. Lightweight and compact.

For more details on these and other Celestron accessories, please ask for the Celestron Accessory Catalog (#93685-91) at your Celestron dealer or contact:

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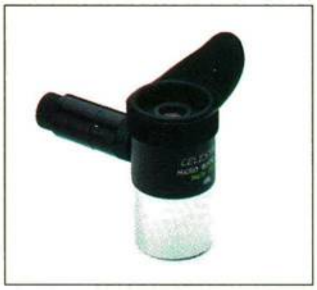
310/ 328-9560 • Call free 1-800-421-1526 • FAX 310/ 212-5835

RADIAL GUIDER—this new guider represents a tremendous improvement over conventional off-axis guiders. The angle of the prism is now tunable! It maintains a fixed rigid camera orientation while the user is free to move the guiding eyepiece radially. Very compact, sleek and easy to use for astrophotography with catadioptrics.

DELUXE ZOOM OCULAR 1-1/4"—just introduced, this eyepiece is the first zoom astronomical eyepiece of extremely high quality. The focal length range of 6.5-18mm allows great lunar and planetary observations. It is multi-coated and extremely compact and lightweight.

BARLOW LENSES—three economical models are offered. The .96", 1-1/4" and 2" units are 2x. The 2" model is fully multi-coated.

REDUCER/CORRECTOR f/6.3—this combination focal reducer and field corrector lens works with Celestron C8's and C11's to make it possible to have a dual focal ratio instrument while optimizing image quality. It is a four-element, fully multi-coated unit. Results are spectacular both photographically and visually.



MICRO GUIDE EYEPIECE—this multi-function guiding eyepiece features a laser-etched reticle with built-in cordless illuminator. The eyepiece is a multi-coated 12.5mm Abbe Orthoscopic (better than standard Orthoscopics or Plössls). Usage possibilities include: direct guiding on stars outside the center of the field of view, greatly improved off-axis guiding and much more.

VIXEN LV EYEPIECES—recently introduced, these Vixen brand eyepieces use the rare earth glass lanthanum to help hold aberrations to an absolute minimum. Ten focal lengths (2.5mm to 30mm) all with a 20mm eye relief! Optical design varies from 6 to 8 elements. The body and eyecup are soft rubber and all are fully multi-coated. The 2.5 and 4mm are as easy to look through as most 7-12mm oculars.

With new and innovative accessories, Celestron's SCT's continue to outperform the competition. This ad has just 12 examples (plus 12 more in a separate ad in this issue) of why you should consider going with the leader in portable visual and photographic telescopes.

Celestron delivers the highest performance - not unnecessary bells and whistles. That is why most of the good astrophotos appearing in magazines are taken with Celestron equipment. Performance/results - not words - are what counts.